REPORT

January 2018

Project Id: COV2017-3

2017 Annual Catalytic Oxidizer Performance Test

Prepared for

Covidien LP
195 McDermott Road
North Haven, CT 06473

Prepared by

Canomara LLC
PO Box 941
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I certify that to the best of my knowledge:

- The information provided in this document is true, accurate, and complete.
- Any deviations from published test methods are identified and described in detail.
- Testing will be conducted according to the approved protocol.
- All deviations, method modifications, or sampling and analytical anomalies will be summarized in the appropriate report narrative(s).

James Canora, QSTI
Project Manager

January 2, 2018
Date

Section **Page**

Appendix

1 INTRODUCTION

1.1 Overview

Canomara LLC was contracted by Covidien LP to conduct the 2017 annual performance test on the catalytic oxidizer used to control ethylene oxide (ETO) emissions from a medical product sterilizer at the North Haven, CT facility. The sterilization process includes two sterilizer chambers vented to a shared control system designed and manufactured by LESNI. The sterilization process is regulated by 40 CFR 63, Subpart O (i.e., the National Emission Standards for Hazardous Air Pollutants for Ethylene Oxide Sterilization Facilities or the MACT rule) and Connecticut Department of Energy and Environmental Protection (DEEP) permits 135-0143 and 135-0144.

As per 40 CFR 63 Subpart O, amended on November 2, 2001, Covidien LP elects to test the catalytic oxidizer annually to determine ethylene oxide destruction efficiency. The specification for the test is contained in 40 CFR 63.363 (b)(4)(i). Subpart O initially required catalyst replacement based upon the manufacturer's recommendation (typically every 5 years); however, the rule was changed and now permits a facility to use the same catalyst until a performance test indicates that the ETO removal efficiency is less than the mandated 99%. If the efficiency is less than 99%, the facility must restore the catalyst as soon as practicable but no later than 180 days after conducting the performance test.

Testing was conducted in accordance with EPA Methods 1, 2, and 18. Gas samples were collected from the oxidizer inlet and outlet in Tedlar bags simultaneously and the bags were analyzed on the following day by gas chromatography. Three 1-hour inlet/outlet sample sets were collected and analyzed. During sampling, the process was operated at a worst-case condition, which included unloading both sterilizers into primary aeration.

1.2 Contact Information

The test was conducted on December 20, 2017 by Evan Bali and Ed Gutfran and supervised by James Canora. The tests were coordinated by Ms. Kimberly Zuraw, Sr. EHS Specialist, with Covidien. There were no regulatory personnel on site. Contact information is as follows:

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1.3 Report Organization

Section 2.0 of this report contains a summary of results. Section 3.0 describes the process operations. Section 4.0 describes the sampling and analytical methods and Section 5.0 describes the quality assurance procedures. Complete data are included in the appendices.

2 RESULTS

The tests showed that ethylene oxide destruction efficiency was greater than 99.80%. The ethylene oxide concentration on the oxidizer outlet was below the Method 18 detection limit on all three tests. Results are summarized in Table 2-1 and complete data are contained in the appendices.

Table 2-1: 2017 Catalytic Oxidizer Performance Test Summary

Test No.	1	2	3	Average	DEEP Permit Limit	Subpart O Permit Limit
Continuous Process Monitoring Data						
Oxidizer Exit Temperature (^{o}C)	159.7	160.4	161.2	160.4		
Emission Test Data						
Oxidizer Inlet Gas Flow Rate (scfm)	6360	6339	6438	6379		
Oxidizer Outlet Gas Flow Rate (scfm) [1]	6360	6339	6438	6379		
Oxidizer Inlet ETO Concentration (ppm-wet)	146.89	113.46	79.07	113.14		
Oxidizer Outlet ETO Concentration (ppm-wet)	<0.21	<0.21	<0.21	<0.21	1.0	1
Oxidizer Inlet ETO Emission Rate (lb/hour) [2]	6.41	4.94	3.49	4.95		
Oxidizer Outlet ETO Emission Rate (lb/hour)	<0.009	<0.009	<0.009	<0.009	<0.059	
Destruction Efficiency (%) [3]	>99.86%	>99.81%	>99.73%	>99.80%		99%

1. Outlet gas flow rate was assumed to be the same as the inlet.
2. lb/hour = ppm-wet x scfm x MW x 15.58 x 10^{-8} MW = molecular weight of ethylene oxide (44.05)
3. Destruction Efficiency = $(ER_{inlet} - ER_{outlet})/ER_{inlet}$ x 100 ER = emission rate (lb/hour)

3 Process Description

Covidien produces a variety of medical and surgical appliances and has recently installed two medical appliance sterilizers. The sterilizers use pure ETO sterilant gas. Emissions from the sterilizer chamber vents and primary aeration vents are controlled with a LENSI catalytic abator system. The sterilization process also includes two secondary aeration rooms and these rooms are vented directly to atmosphere as the emission concentration is less than 1 ppm.

3.1 Sterilization and Aeration Process Description

Product to be sterilized is waiting in the staging/preconditioning room (PCR) where it gets exposed for approximately 6 hours to temperatures between 67° - 115° F and humidity of 40% – 70% depending on specific product's needs.

There are two sterilizer chambers, each equipped for 6 pallet loads. Pallets dimensions do not exceed the following dimensions: width 42" x height 71" x length 48". The system was initially designed for four chambers; however, only two were built. Packaged medical products are loaded into the chambers, conditioned to specified temperature and humidity and sterilized with a maximum 50 pound charge of ETO. The sterilization cycle times are different for different products with a range of 9 to 22 hours.

At the end of the sterilization cycle, the chamber gas is evacuated to the LESNI and product is conveyed to the primary aeration rooms. The evacuation process includes multiple pumped evacuations followed by nitrogen charges and this process is referred to as washes. The number of washes is variable depending on the product type, but all evacuations are conducted with the same vacuum pumps exhausted to the balancer tank.

Each sterilizer chamber has a dedicated primary aeration room and each room is equipped with multiple gas collection intakes near the floor. The primary aeration time is typically 12 hours; however, the ETO concentration in the room must be less than 1.5 ppm to end the cycle. After primary aeration, product pallets are moved with a fork-lift to either of the two secondary aeration rooms. One room is dedicated to suture products and the other room is dedicated to polymer products. Both secondary rooms are exhausted with a shared pair of ID fans located on the roof. The two fans are operated in parallel and provide a redundant exhaust fan in the event of failure. The final exhaust to atmosphere is through a 36-inch diameter stack.

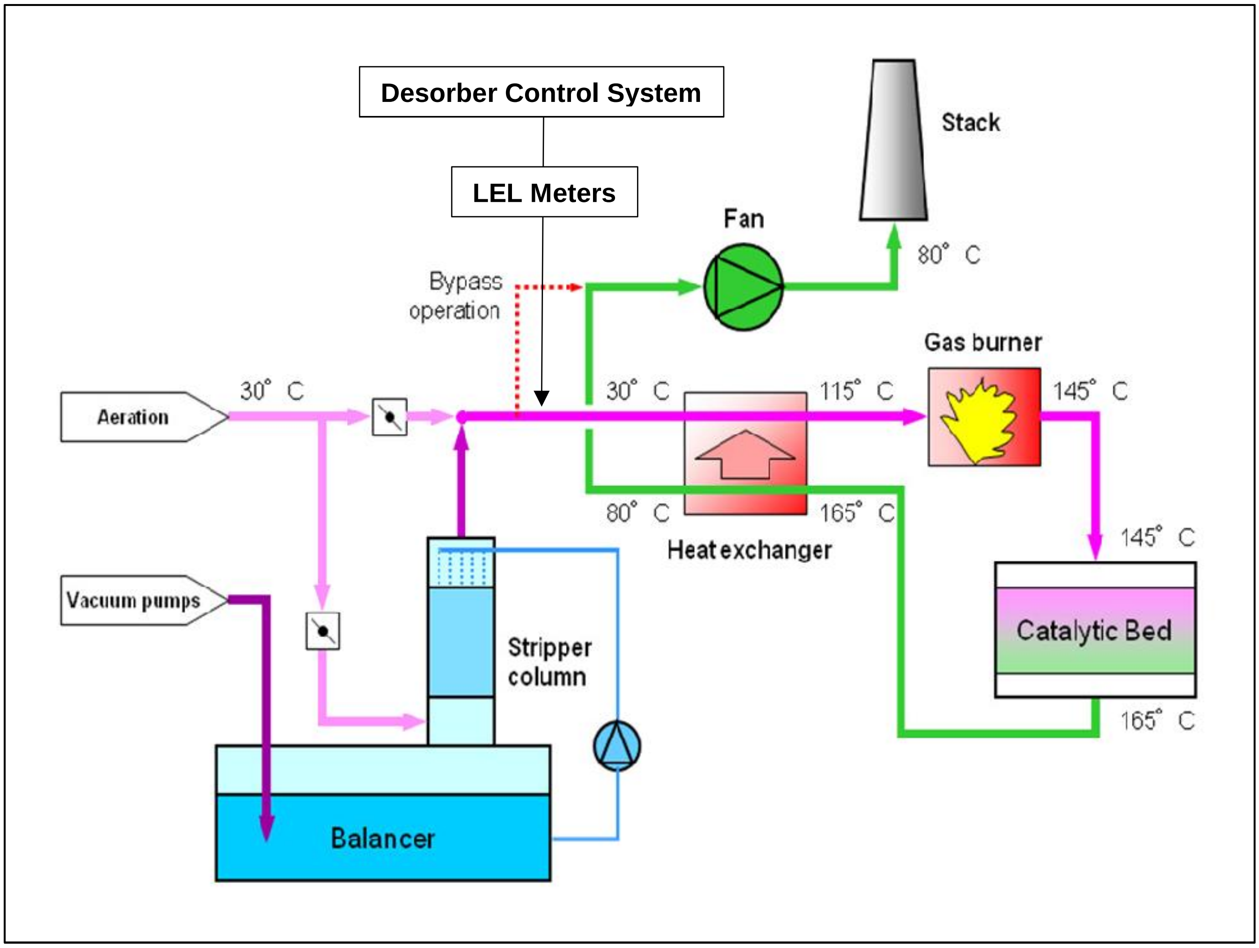
3.2 LESNI Abator System

The LESNI Catalytic abator system is designed to control ETO emissions from chamber venting and primary aeration using catalytic oxidation preceded by a balancer that buffers high concentration chamber vent emissions. The LESNI converts ETO to CO_2 and H_2O without chemical additives (sulfuric acid) and without producing ethylene glycol waste. The system is designed to meet the 99% reduction and 1.0 ppm MACT limits. A simplified process schematic is presented in Figure 3-1.

The LESNI receives exhaust gas from the primary aeration rooms through a common duct and from the chamber vents via the balancer. The exhaust fan is located after the oxidizer and this fan maintains a negative pressure on the aeration rooms, the balancer and all associated equipment and ductwork. Aeration rooms are exhausted through floor level intakes and these intakes are connected below the roof to a common 24-inch duct. On the roof, the common aeration room duct is split to two booster fans that are engineered to maintain a negative pressure on the aeration room in the event of a failure with the LESNI fan. The ETO concentration in the primary aeration exhaust is low (typically less than 100 ppm).

The sterilizer chamber evacuations generate high concentration ETO exhaust streams and the LESNI is designed to buffer these high concentrations with an aqueous absorber/desorber identified as the balancer, so that the oxidizer is never subjected to un-buffered gas. The primary functional components of the chamber exhaust system are (1) water sealed vacuum pumps, (2) sparger tubes, (3) balancer tank, (4) stripper column, and (5) desorber control system. These components are shown in Figure 3-1. Each chamber has a single dedicated vacuum pump rated for 250 scfm. Each vacuum pump is directly piped to a sparger tube on the balancer tank that exits below the tank water level so that the incoming gas is bubbled through the water to absorb ETO. The vacuum pumps have water seals and the seal is formed from balancer tank water pumped to and from the vacuum pumps. The balancer tank contains 15,000 liters of water which can absorb up to 450 pounds of ETO. The stripper column physically rests on the top of the balancer tank and water is continuously pumped from the tank to spray nozzles located on the top of the stripper column. The sprayed water falls through the column back into the tank through a counter current air flow that enters the bottom of the column. The counter current air flow is a slipstream of the primary aeration exhaust, so that in effect, the balancer absorbs high concentration chamber vent ETO emissions in water and then uses the low concentration primary aeration exhaust air to strip ETO from the water. The balancer tank water temperature is also monitored and controlled to a range of 5 °C to 28 °C.

Figure 3-1
Process Schematic



ETO desorption from the balancer tank is controlled to limit the rate of ETO entering the catalytic oxidizer. This control is conducted automatically with three procedures including the water spray rate at the top of the stripper column, counter current air flow rate through the column (this air flow is a slipstream of the primary aeration exhaust) and a pair of redundant LEL meters located 30 inches downstream of the stripper column return pipe. The control setting at Covidien is 2.5% of the LEL which is equivalent to 750 ppm of ETO. When the LEL is low, the desorption rate is maximized with low water spray rate on to the top of the column and high counter current air flow rate. When the LEL increases as chamber venting occurs, the water spray rate is increased, and counter current air flow rate is reduced with a controlled damper to maintain LEL below the set point. The position of this stripper air control damper is a measured and recorded process parameter.

The balancer stripper exit re-combines with the primary aeration exhaust and the combined gas is preheated with a shell and tube type heat exchanger and then enters the gas fired heater. The heat exchanger and gas fired heater raise the temperature to the required catalyst inlet temperature which is 145 ^{o}C. The preheated gas enters the catalytic oxidizer and three parallel beds oxidize ETO. The catalyst bed exit gas temperature increases across the beds and temperature is monitored at the catalyst bed inlet and at the outlets of all three beds. Recorded temperatures include the catalyst inlet, catalyst bed outlets, and the average catalyst bed outlet. The average catalyst bed outlet temperature is the set to a minimum of 150 ^{o}C. The exhaust fan is installed after the catalytic abator, and this single fan provides the necessary suction for extracting the process air through the system maintaining a negative pressure on the exhaust process.

3.3 LESNI Process Monitoring

The sterilizer chamber and LESNI are monitored and controlled with a computer-based control system operated in a state of the art control room. Temperature, humidity, pressure and ETO charge weights are primary parameters monitored on each sterilizer chamber. The LESNI abator is monitored extensively and the principal parameters used for control are LEL sensors on the balancer and the combined catalyst bed outlet temperature. The oxidizer temperature monitoring complies with 63.363(b)(3) and 63.364(c).

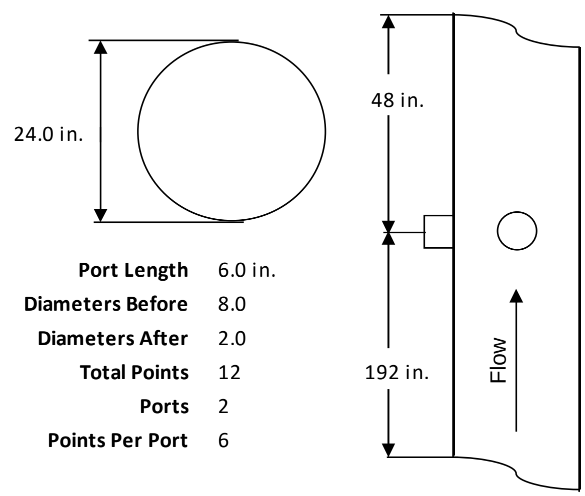
4 SAMPLING & ANALYTICAL PROCEDURES

ETO emissions were measured concurrently at the oxidizer inlet and outlet and destruction efficiency was demonstrated on a mass basis. The tables and paragraphs below describe the test methods and detailed method descriptions are contained in Appendix A.

Table 4-1: Reference Methods

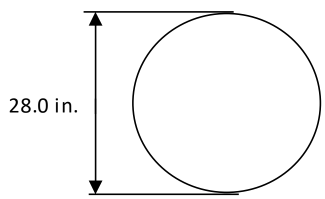
Method	Description
EPA 1	Sample and Velocity Traverses for Stationary Sources
EPA 2	Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)
EPA 18	Measurement of Gaseous Organic Compound Emissions by Gas Chromatography

Figure 4-2
Inlet Traverse Points

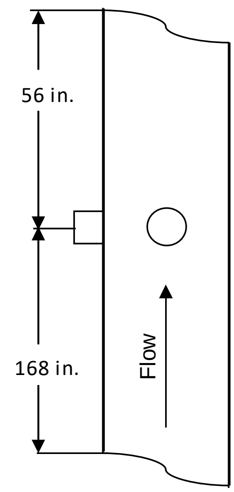


Traverse Point	Duct Depth	Probe Measurement
1	1.0	7.0
2	3.5	9.5
3	7.1	13.1
4	16.9	22.9
5	20.5	26.5
6	23.0	29.0

Figure 4-3
Outlet Traverse Points



Port Length	6.0 in.
Diameters Before	6.0
Diameters After	2.0
Total Points	16
Ports	2
Points Per Port	8



Traverse Point	Duct Depth	Probe Measurement
1	0.9	6.9
2	2.9	8.9
3	5.4	11.4
4	9.1	15.1
5	18.9	24.9
6	22.6	28.6
7	25.1	31.1
8	27.1	33.1

5 Quality Assurance

CM's quality assurance program is designed so that work is performed by competent, experienced individuals using properly calibrated equipment, approved procedures for sample collection, recovery, and analysis and proper documentation. This ensures the integrity of data collected, processed, and reported on each project.

5.1 Sampling and Flow Equipment

Sampling and measurement equipment, including continuous analyzers, recorders, pitot tubes, dry-gas meters, orifice meters, thermocouples, probes, nozzles, and any other pertinent apparatus, is uniquely identified, undergoes preventive maintenance, and is calibrated before and after each field effort, following written procedures and acceptance criteria. Calibrations are performed with standards traceable to the National Institute for Science and Technology (NIST) when required. Standards used include wet-test meters, standard pitot tubes, and NIST Standard Reference Materials. Records of all calibration data are maintained in CM files.

5.2 EPA Method 18

Sampling and analytical quality control for EPA Method 18 include sampling flow rate calibration, leak checking before each test, bag wall loss recovery study, triplicate analyses, pre-analysis multi-level calibration and a post-analysis single-level calibration. In addition, any dilutions made on samples or calibration gases will be verified by the testing firm. The Teflon tube used for sampling transfer lines will be new, steel probes will be new, and dedicated inlet/outlet equipment will be used. The sampling trains will be leak checked before each test run using a flow leak check procedure. The sampling probe inlet is sealed and the sampling train is evacuated to a vacuum greater than 5 inches of Hg. An acceptable leak rate is no observed flow over a 30 second period.

The calibration precision is measured during the initial calibration by analyzing each calibration gas three times and each of the three runs was within 5% of the mean. Bag wall loss is determined by spiking one of the samples with a known amount of ETO and then re-analyzing the spiked sample. The spike recovery is a calculated in accordance with EPA Method 18 and recovery must be ±30%.

APPENDIX A

Gas Flow Rate Data

Covidien - North Haven, CT | **EPA 1, 2, 18** | **Canomara LLC**
Oxidizer Inlet (24-inch horizontal pipe) | **Summary Table** | **Source Testing Services**

Item	Description	Run 1	Run 2	Run 3	Average	Compliance
		'Run 1'!	'Run 2'!	'Run 3'!		
Date	*Test Date*	12/20/2017	12/20/2017	12/20/2017		
Start	*Run Start Time*	14:42	15:44	16:48		
Finish	*Run Finish Time*	15:42	16:44	17:48		
θ	*Net Run Time, minutes*	60.0	60.0	60.0	60.0	
N_{tp}	*Net Traversing Points*	12	12	12	12	
C_p	*Pitot Tube Coeficient*	0.840	0.840	0.840	0.840	
P_{Br}	*Barometric Pressure, inches of Mercury*	29.99	29.99	29.99	29.99	
% H_2O	*Moisture Content of Stack Gas, %*	1.2	1.2	1.2	1.2	
M_{fd}	*Dry Mole Fraction*	0.988	0.988	0.988	0.988	
%CO_2	*Carbon Dioxide, %*	0.00	0.00	0.00		
%O_2	*Oxygen, %*	20.90	20.90	20.90	20.90	
% CO + N_2	*Carbon Monoxide & Nitrogen, %*	79.1	79.1	79.1	79.1	
M_d	*Dry Molecular Weight, lb/lb-Mole*	28.84	28.84	28.84	28.84	
M_s	*Wet Molecular Weight, lb/lb-Mole*	28.70	28.70	28.70	28.70	
P_g	*Flue Gas Static Pressure, inches of* H_2O	-2.80	-3.00	-2.90	-2.90	
P_s	*Absolute Flue Gas Pressure, inches of Mercury*	29.78	29.77	29.78	29.78	
T_s	*Average Stack Gas Temperature, °F*	68.8	69.6	69.5	69.3	
ΔP_{avg}	*Average Velocity Head, inches of* H_2O	0.363	0.361	0.374	0.366	
A_s	*Stack Crossectional Area, square feet*	3.1	3.1	3.1	3.1	
FLOW						
v_s	*Average Stack Gas Velocity, fps*	33.9	33.9	34.4	34.1	
$v_{s\ (fpm)}$	*Average Stack Gas Velocity, fpm*	2,037	2,034	2,065	2,045	
Q_{aw}	*Actual Wet Volumetric Flue Gas Flow Rate, acfm*	6,399	6,390	6,487	6,425	
Q_{sw}	*Standard Wet Volumetric Flue Gas Flow Rate, scfm*	6,360	6,339	6,438	6,379	
$Q_{sw\ (scfh)}$	*Standard Wet Volumetric Flue Gas Flow Rate, scfh*	381,574	380,356	386,281	382,737	
Q_{sd}	*Standard Dry Volumetric Flow Rate, dscfm*	6,283	6,262	6,360	6,302	
$Q_{sd\ (dscfh)}$	*Standard Dry Volumetric Flow Rate, dscfh*	376,953	375,749	381,603	378,102	
ETHYLENE OXIDE						
$EO_{ppm\text{-}inlet}$	Ethylene Oxide Concentration, ppm-wet	146.89	113.46	79.07	113.14	
$EO_{lb/hour\text{-}inlet}$	Ethylene Oxide Emission Rate, lb/hour	6.41	4.94	3.49	4.95	

Flow Data

Project Id	Client	Facility	Source Id	Location	Pitot Tube Leak Check	Pitot Tube Id	Cp	Date	Operators
COV2017-3	Medtronic	N. Haven	oxidizer	Inlet	+ ✓ -	4-1	0.84	12-20-17	EB / EG

Run	Time	Static (in H_2O)
1	1433	-2.8

Traverse Point	Pitot Δ P (in H_2O)	Stack Temp (°F)
A 1	.35	68
2	.38	69
3	.40	69
4	.41	70
5	.35	68
6	.31	68
B 1	.36	69
2	.40	69
3	.41	70
4	.38	70
5	.33	69
6	.27	67

Run	Time	Static (in H_2O)
2	1542	-3.0

Traverse Point	Pitot Δ P (in H_2O)	Stack Temp (°F)
A 1	.33	70
2	.37	70
3	.41	70
4	.41	69
5	.36	69
6	.30	68
B 1	.37	70
2	.41	70
3	.40	69
4	.36	70
5	.32	70
6	.29	70

Run	Time	Static (in H_2O)
3	1644	-2.9

Traverse Point	Pitot Δ P (in H_2O)	Stack Temp (°F)
A 1	.35	70
2	.34	70
3	.39	71
4	.42	69
5	.38	69
6	.32	68
B 1	.35	70
2	.40	70
3	.40	71
4	.35	69
5	.33	69
6	.27	68

Run	Time	Static (in H_2O)

Traverse Point	Pitot Δ P (in H_2O)	Stack Temp (°F)

Notes: P_{bar} 29.99

Non-Isokinetic Source Sampling Data Sheet

Project Id	Project Client	Project Facility	Source Id	Source Location	Dry Gas Meter Id	Dry Gas Meter ΔH@	Dry Gas Meter Y	Barometric Pressure (in Hg)	Date	Operators
COV2017-3	Medtronic	North Haven	oxidizer	Inlet	√2059		1.0061	29.91	12-20-2017	EB/EG

Run	Time	Initial Leak Check in Hg	Initial Leak Check cfm	Final Leak Check in Hg	Final Leak Check cfm
1	1442-1542	5	0.00	5	0.00

Elapsed Time (min)	DGM Volume (liters)	Ball Flow Meter Setting	Temperature (°F) Impinger	Temperature (°F) DGM In	Temperature (°F) DGM Out	Vacuum (in Hg)
0	0.0	0.1		38		1
10		0.1		39		1
20		0.1		40		1
30		0.1		40		1
40		0.1		41		1
50		0.1		42		1
60	6.019		Initial Weight (g)	—	Final Weight (g)	—

Run	Time	Initial Leak Check in Hg	Initial Leak Check cfm	Final Leak Check in Hg	Final Leak Check cfm
2	1544-1644	4	0.00	5	0.00

Elapsed Time (min)	DGM Volume (liters)	Ball Flow Meter Setting	Temperature (°F) Impinger	Temperature (°F) DGM In	Temperature (°F) DGM Out	Vacuum (in Hg)
0	0.0	0.1		41		
10		0.1		43		
20		0.1		44		
30		0.1		46		
40		0.1		48		
50		0.1		50		
60	6.642		Initial Weight (g)	—	Final Weight (g)	—

Run	Time	Initial Leak Check in Hg	Initial Leak Check cfm	Final Leak Check in Hg	Final Leak Check cfm
3	1648-1748	6	0.00	5	0.00

Elapsed Time (min)	DGM Volume (liters)	Ball Flow Meter Setting	Temperature (°F) Impinger	Temperature (°F) DGM In	Temperature (°F) DGM Out	Vacuum (in Hg)
0	0.0	0.1		50		1
10		0.1		50		1
20		0.1		52		1
30		0.1		53		1
40		0.1		54		1
50		0.1		54		1
60	6.239		Initial Weight (g)	—	Final Weight (g)	—

Run	Time	Initial Leak Check in Hg	Initial Leak Check cfm	Final Leak Check in Hg	Final Leak Check cfm

Elapsed Time (min)	DGM Volume (liters)	Ball Flow Meter Setting	Temperature (°F) Impinger	Temperature (°F) DGM In	Temperature (°F) DGM Out	Vacuum (in Hg)
0						
10						
20						
30						
40						
50						
60			Initial Weight (g)		Final Weight (g)	

Non-Isokinetic Source Sampling Data Sheet

Project Id	Project Client	Project Facility	Source Id	Source Location	Dry Gas Meter Id	Dry Gas Meter ΔH@	Dry Gas Meter Y	Barometric Pressure (in Hg)	Date	Operators
COV2017-3	Medtronic	North Haven	Stabilizer	Outlet	V2060		2	29.91	12-20-17	SB / EG

Run	Time	Initial Leak Check in Hg	Initial Leak Check cfm	Final Leak Check in Hg	Final Leak Check cfm
1	1442 - 1542	4	0.00	4	0.00

Elapsed Time (min)	DGM Volume (liters)	Ball Flow Meter Setting	Temperature (°F) Impinger	Temperature (°F) DGM In	Temperature (°F) DGM Out	Vacuum (in Hg)
0	0.0	0.1		37		
10		0.1		38		
20		0.1		40		
30		0.1		41		
40		0.1		41		
50		0.1		41		
60	6.111		Initial Weight (g)	—	Final Weight (g)	—

Run	Time	Initial Leak Check in Hg	Initial Leak Check cfm	Final Leak Check in Hg	Final Leak Check cfm
2	1544 - 1644	5	0.00	4	0.00

Elapsed Time (min)	DGM Volume (liters)	Ball Flow Meter Setting	Temperature (°F) Impinger	Temperature (°F) DGM In	Temperature (°F) DGM Out	Vacuum (in Hg)
0	0.0	0.1		40		
10		0.1		41		
20		0.1		43		
30		0.1		44		
40		0.1		46		
50		0.1		48		
60	6.350		Initial Weight (g)	—	Final Weight (g)	—

Run	Time	Initial Leak Check in Hg	Initial Leak Check cfm	Final Leak Check in Hg	Final Leak Check cfm
3	1648 - 1748	6	0.00	5	0.00

Elapsed Time (min)	DGM Volume (liters)	Ball Flow Meter Setting	Temperature (°F) Impinger	Temperature (°F) DGM In	Temperature (°F) DGM Out	Vacuum (in Hg)
0	0.0	0.1		48		
10		0.1		49		
20		0.1		50		
30		0.1		52		
40		0.1		53		
50		0.1		53		
60	6.483		Initial Weight (g)	—	Final Weight (g)	—

Run	Time	Initial Leak Check in Hg	Initial Leak Check cfm	Final Leak Check in Hg	Final Leak Check cfm

Elapsed Time (min)	DGM Volume (liters)	Ball Flow Meter Setting	Temperature (°F) Impinger	Temperature (°F) DGM In	Temperature (°F) DGM Out	Vacuum (in Hg)
0						
10						
20						
30						
40						
50						
60			Initial Weight (g)		Final Weight (g)	

APPENDIX B

EPA Method 18 Data

Oxidizer Outlet Method 18 Initial Calibration

20-Dec-17

Covidien

Standards

	Low	Mid	High
Cylinder ID		EA0011733	EA0077506
Expiration Date		5/21/2017	5/21/2017
EO (ppm)	0.0	5.00	10.0

High

Compound	Conc	Injection									Average	
		15			16			17				
		Area	Conc	% Dev	Area	Conc	% Dev	Area	Conc	% Dev	Area	Conc
EO	10.00	23.32	9.71	1.50%	24.67	10.27	-4.19%	23.04	9.59	2.69%	23.68	9.86

Mid

Compound	Conc	Injection									Average	
		21			22			23				
		Area	Conc	% Dev	Area	Conc	% Dev	Area	Conc	% Dev	Area	Conc
EO	5.00	12.02	5.01	5.35%	12.82	5.34	-0.95%	13.26	5.23	-4.40%	12.70	5.19

Oxidizer Outlet Method 18 Summary

20-Dec-17

Covidien

Outlet 1

Compound	Concentration (ppm)				Deviation			Recovery	Corrected (ppm)
	24	25	26	Average					
EO	<0.20	<0.20	<0.20	<0.20	0.0%	0.0%	0.0%	0.94	<0.21

Outlet 2

Compound	Concentration (ppm)				Deviation			Recovery	Corrected (ppm)
	27	28	29	Average					
EO	<0.20	<0.20	<0.20	<0.20	0.0%	0.0%	0.0%	0.94	<0.21

Outlet 3

Compound	Concentration (ppm)				Deviation			Recovery	Corrected (ppm)
	30	31	32	Average					
EO	<0.20	<0.20	<0.20	<0.20	0.0%	0.0%	0.0%	0.94	<0.21

Oxidizer Outlet Method 18 Summary

20-Dec-17

Covidien

Inlet 1

Compound	Concentration (ppm)				Deviation			Recovery	Corrected (ppm)
	33	34	35	Average					
EO	131.6863	140.9206	142.6296	138.4122	4.9%	-1.8%	-3.0%	0.94	146.89

Inlet 2

Compound	Concentration (ppm)				Deviation			Recovery	Corrected (ppm)
	36	37	38	Average					
EO	108.9458	106.4617	105.3232	106.9102	-1.9%	0.4%	1.5%	0.94	113.46

Inlet 3

Compound	Concentration (ppm)				Deviation			Recovery	Corrected (ppm)
	39	40	41	Average					
EO	77.3678	72.0244	74.1281	74.5068	-3.8%	3.3%	0.5%	0.94	79.07

Oxidizer Outlet Method 18 Recovery Study Summary

20-Dec-17

EPA Method 18

Covidien

Recovery Summary

Compound	Sample ID	Sample Volume (ml)	(u) Un-Spiked Sample Response (ppm)	Sample Mass	Standard Volume (ml)	Standard Conc (ppm)	Standard Mass	Spiked Bag Total Conc (ppm)	(s) Theoretical Spike Conc (ppm)	(t) Spiked Sample Response (ppm)	(t-u)/s Recovery (%)
EO	1	2000	0.0	0	2000	10.0	20000	5.00	5.00	4.71	94%

Spiked Sample Analysis

Compound	Concentration (ppm)				Deviation		
	42	43	44	average (t)			
EO	4.6303	4.7747	4.7297	4.7116	1.7%	-1.3%	-0.4%

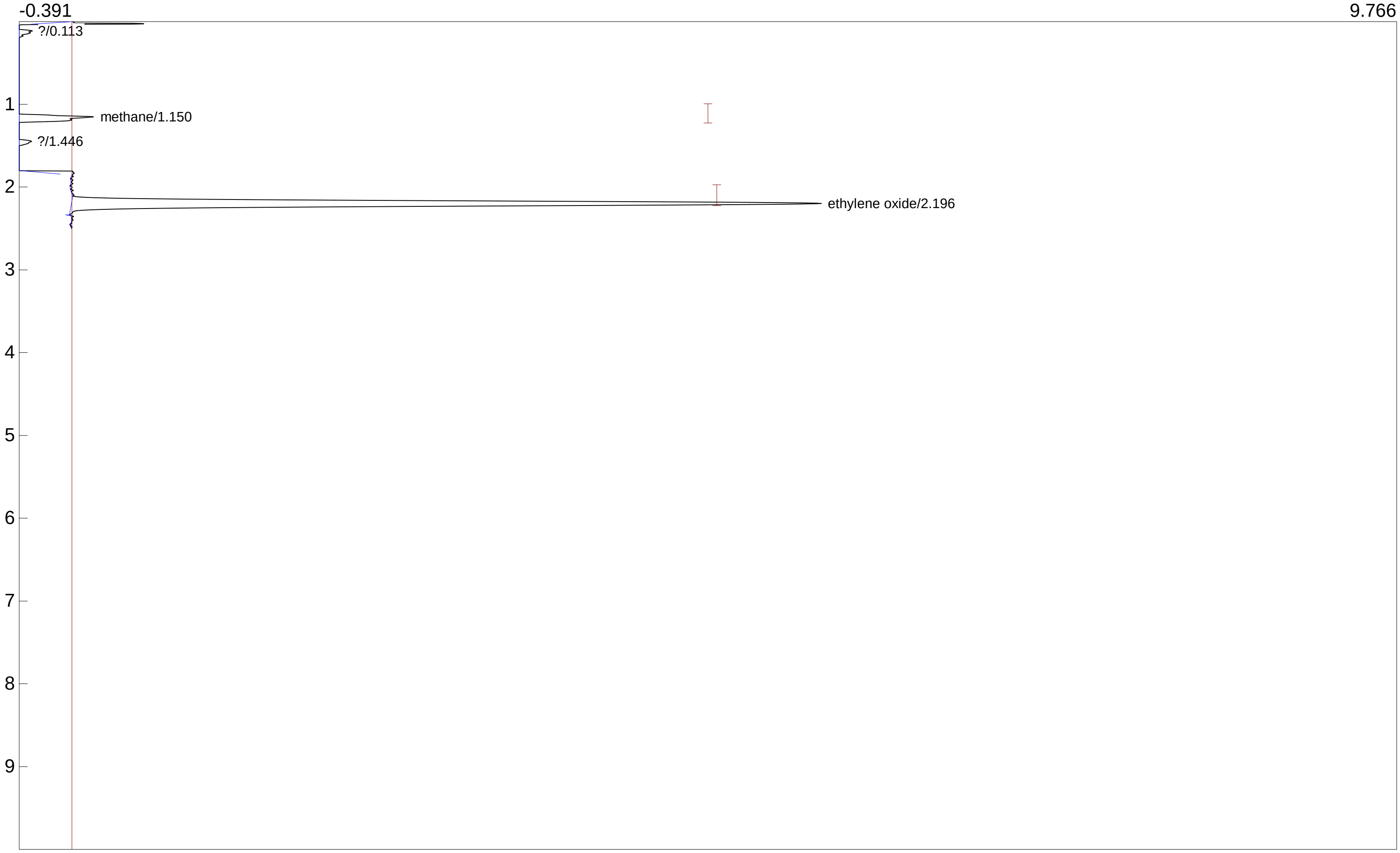
Oxidizer Outlet Method 18 Post Test Calibration

20-Dec-17

Covidien

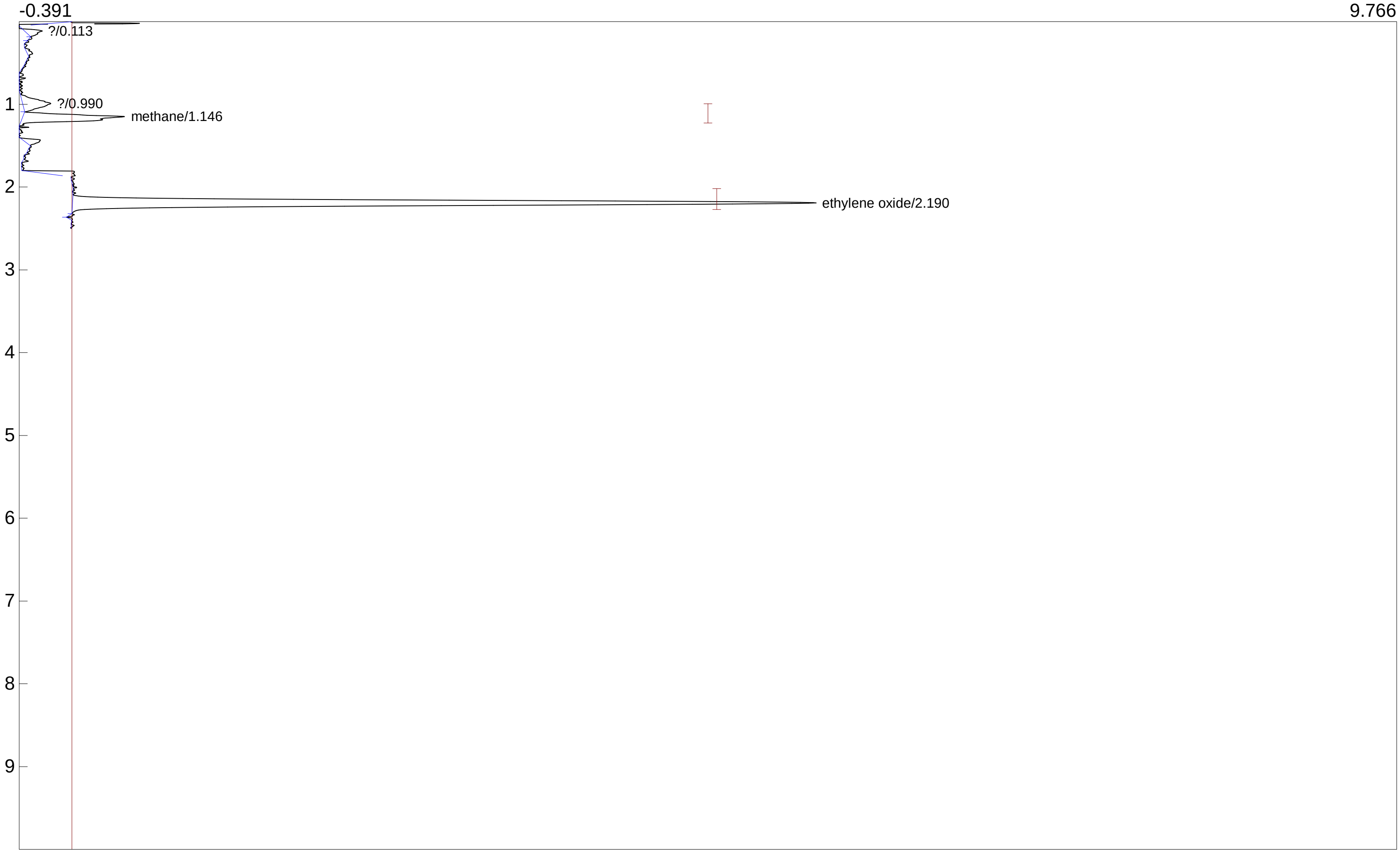
Mid Post Cal

Compound	Conc	Injection									Average		Accuracy	Drift
		45			46			47						
		Area	Conc	% Dev	Area	Conc	% Dev	Area	Conc	% Dev	Area	Conc		
EO	10.00	23.9203	9.9607	4.3%	25.7334	10.7157	-3.0%	25.298	10.5344	-1.3%	24.98	10.40	4.04	5.24%



Component	Retention	Area	Height	External	Units
methane	1.150	3.5626	0.770	0.7275	
ethylene oxide	2.196	23.3224	5.532	9.7117	ppm
		26.8850		10.4393	

Component	Retention	Area	Height	External	Units
methane	1.156	1.8998	0.576	0.3880	
ethylene oxide	2.106	12.8240	3.190	5.3401	ppm
		14.7238		5.7280	

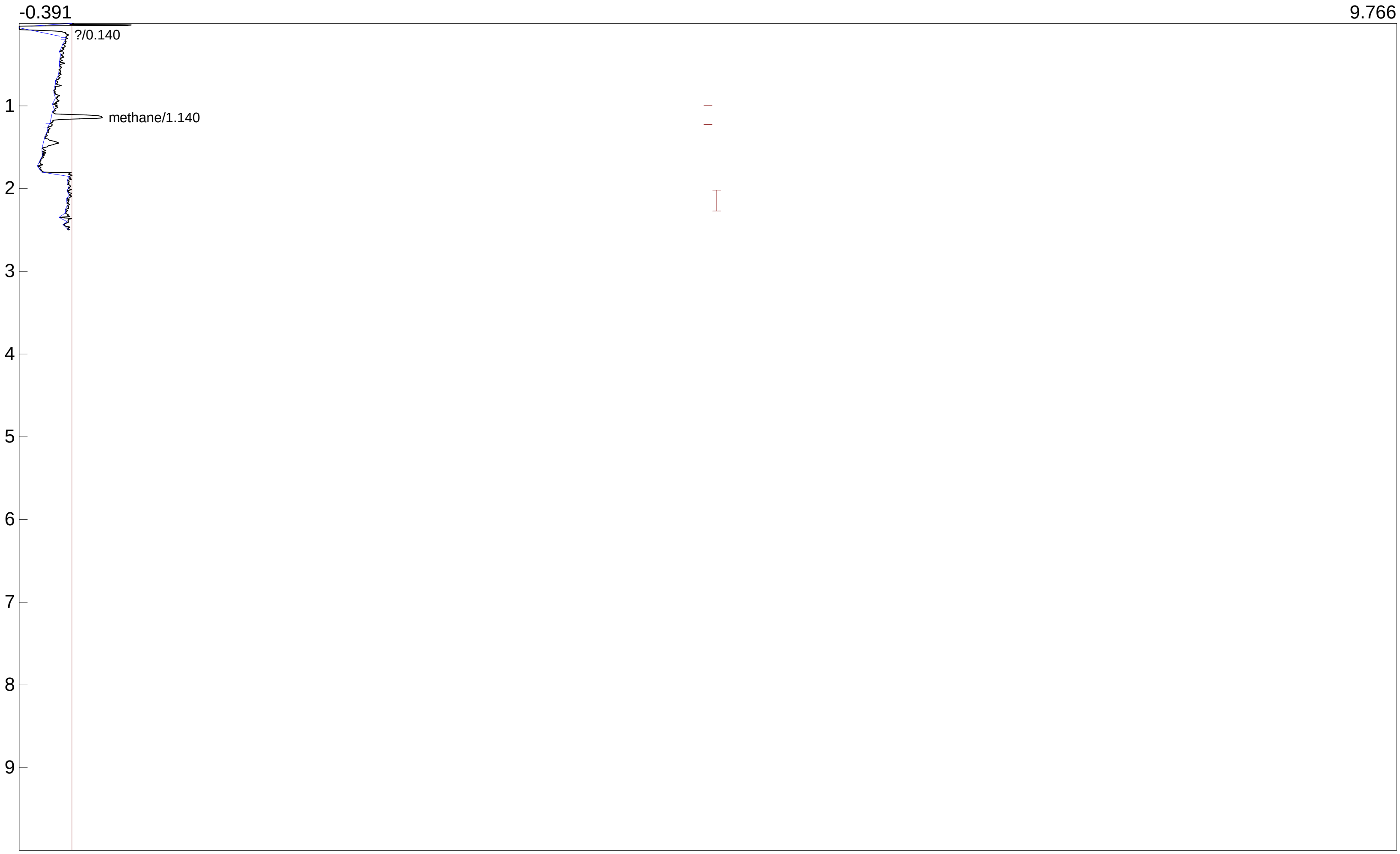


Component	Retention	Area	Height	External	Units
methane	1.146	3.5900	0.760	0.7331	
ethylene oxide	2.190	23.0388	5.482	9.5936	ppm
		26.6288		10.3268	

Component	Retention	Area	Height	External	Units
methane	1.156	1.8503	0.569	0.3779	
ethylene oxide	2.106	12.0327	2.991	5.0106	ppm
		13.8830		5.3884	

Component	Retention	Area	Height	External	Units
methane	1.156	1.8998	0.576	0.3880	
ethylene oxide	2.106	12.8240	3.190	5.3401	ppm
		14.7238		5.7280	

Component	Retention	Area	Height	External	Units
methane	1.156	1.8171	0.549	0.3711	
ethylene oxide	2.106	13.2624	3.262	5.5226	ppm
		15.0795		5.8937	



Component	Retention	Area	Height	External	Units
methane	1.140	1.2018	0.380	0.2454	
		1.2018		0.2454	

Component	Retention	Area	Height	External	Units
methane	1.163	196.0744	66.633	40.0405	
		196.0744		40.0405	

Component	Retention	Area	Height	External	Units
methane	1.166	196.5990	66.584	40.1476	
		196.5990		40.1476	

Component	Retention	Area	Height	External	Units
methane	1.170	196.7844	66.736	40.1854	
		196.7844		40.1854	

Component	Retention	Area	Height	External	Units
methane	1.166	199.7988	67.688	40.8010	
		199.7988		40.8010	

Component	Retention	Area	Height	External	Units
methane	1.163	200.2084	67.729	40.8847	
		200.2084		40.8847	

Component	Retention	Area	Height	External	Units
methane	1.166	199.8938	68.053	40.8204	
		199.8938		40.8204	

Component	Retention	Area	Height	External	Units
methane	1.163	201.0360	67.980	41.0537	
		201.0360		41.0537	

Component	Retention	Area	Height	External	Units
methane	1.166	201.1912	67.880	41.0854	
		201.1912		41.0854	

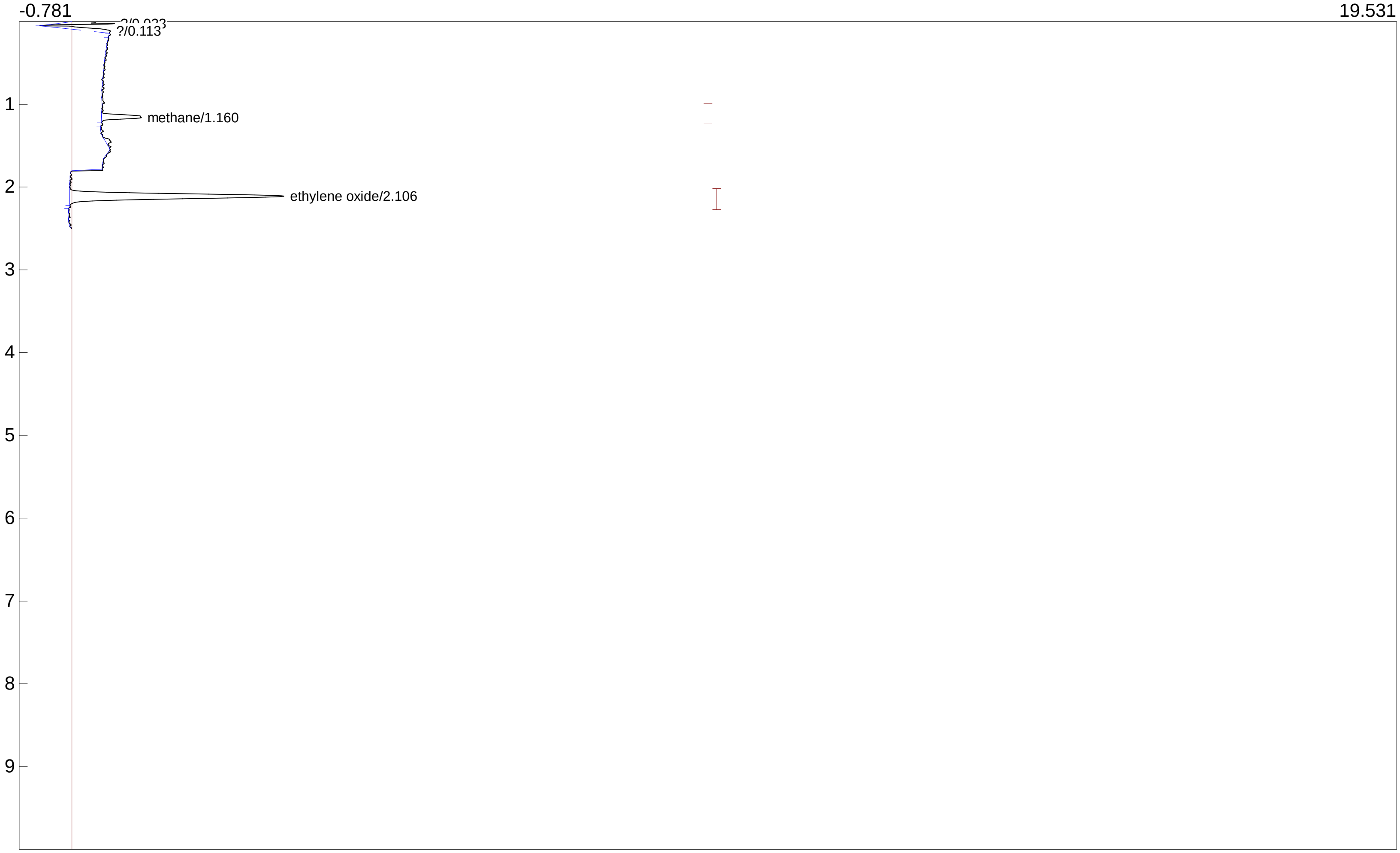
Component	Retention	Area	Height	External	Units
methane	1.170	200.6350	67.964	40.9718	
		200.6350		40.9718	

Component	Retention	Area	Height	External	Units
methane	1.160	3.9813	1.008	8.1302	
ethylene oxide	2.110	31.6240	7.781	131.6863	ppm
		35.6053		139.8165	

Component	Retention	Area	Height	External	Units
methane	1.163	2.9992	0.941	6.1247	
ethylene oxide	2.113	33.8416	8.293	140.9206	ppm
		36.8408		147.0453	

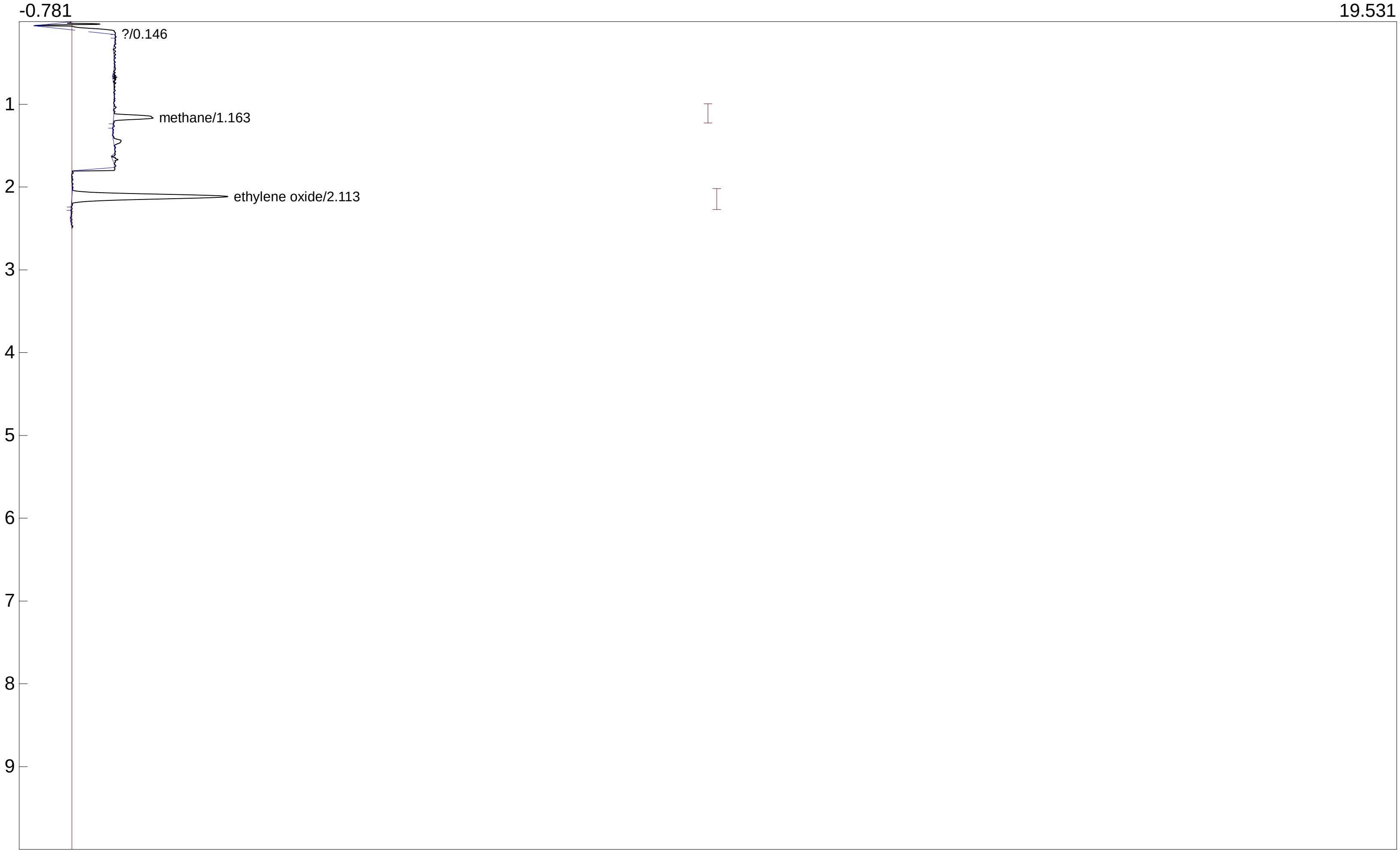
Component	Retention	Area	Height	External	Units
methane	1.166	3.0062	0.907	6.1390	
ethylene oxide	2.110	34.2520	8.399	142.6296	ppm
		37.2582		148.7686	

Component	Retention	Area	Height	External	Units
methane	1.160	1.9370	0.583	7.9111	
ethylene oxide	2.110	13.0816	3.229	108.9468	ppm
		15.0186		116.8579	

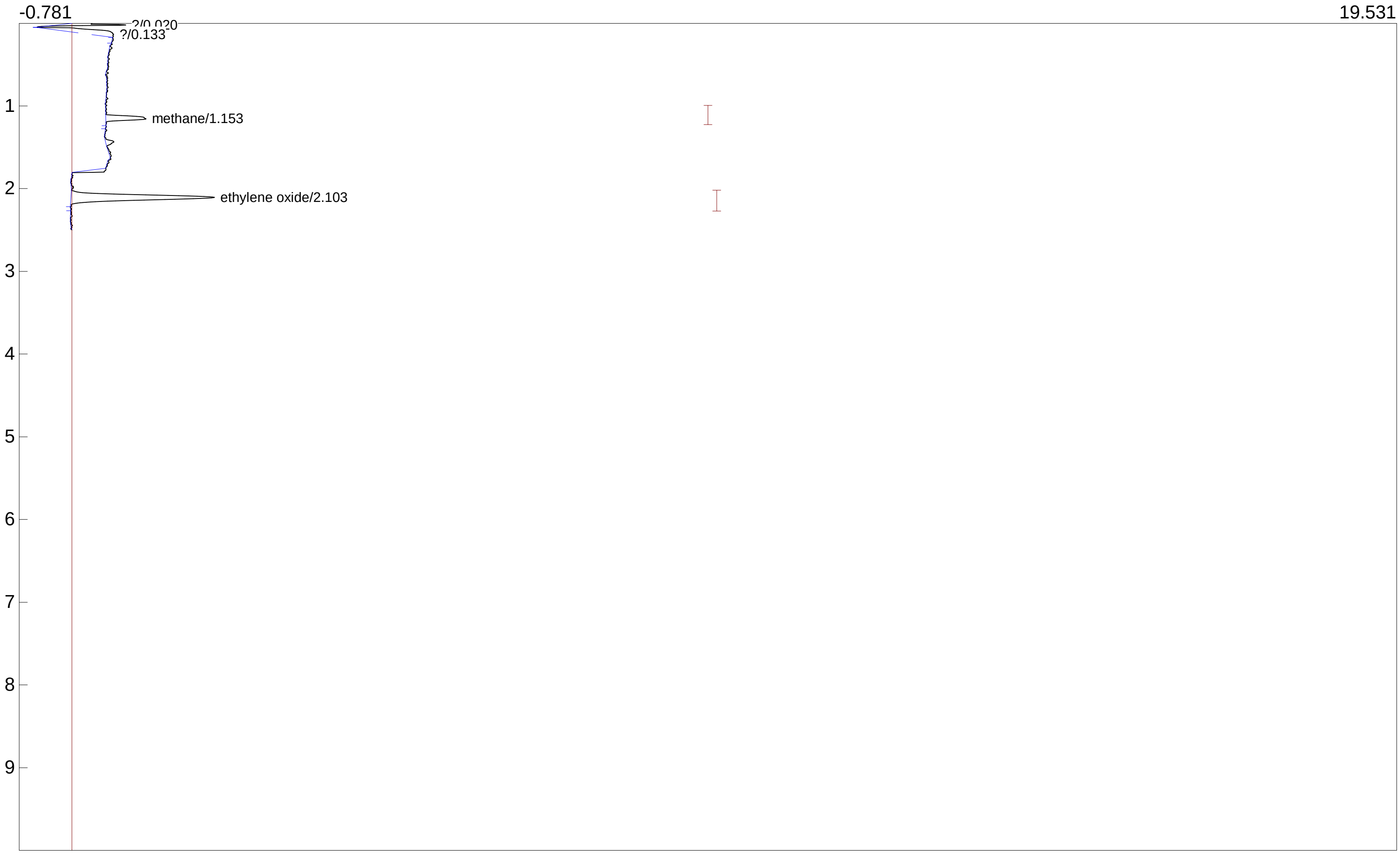


Component	Retention	Area	Height	External	Units
methane	1.160	1.9518	0.591	7.9716	
ethylene oxide	2.106	12.7832	3.162	106.4617	ppm
		14.7350		114.4332	

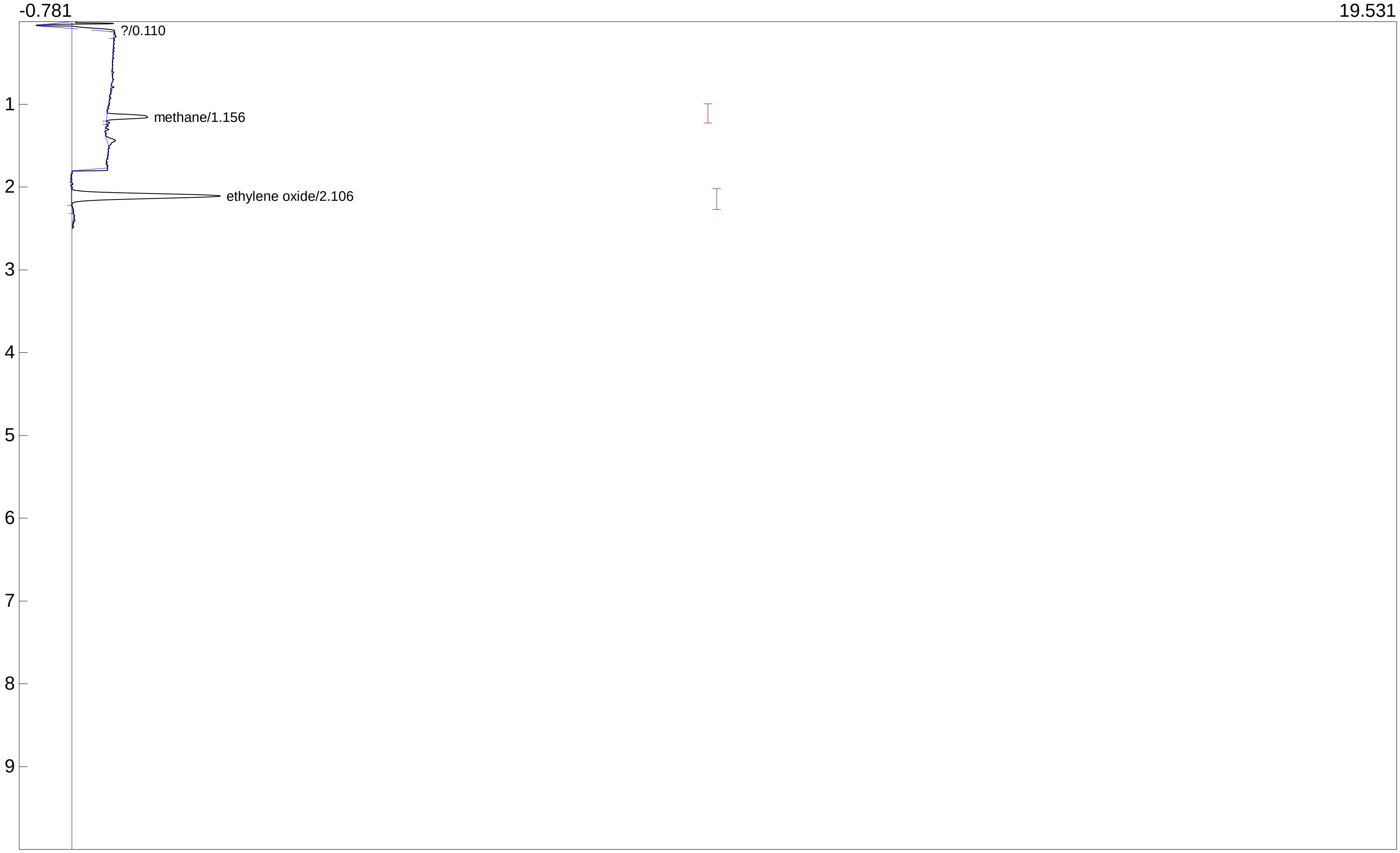
Component	Retention	Area	Height	External	Units
methane	1.156	1.9973	0.599	8.1574	
ethylene oxide	2.110	12.6465	3.128	105.3232	ppm
		14.6438		113.4806	



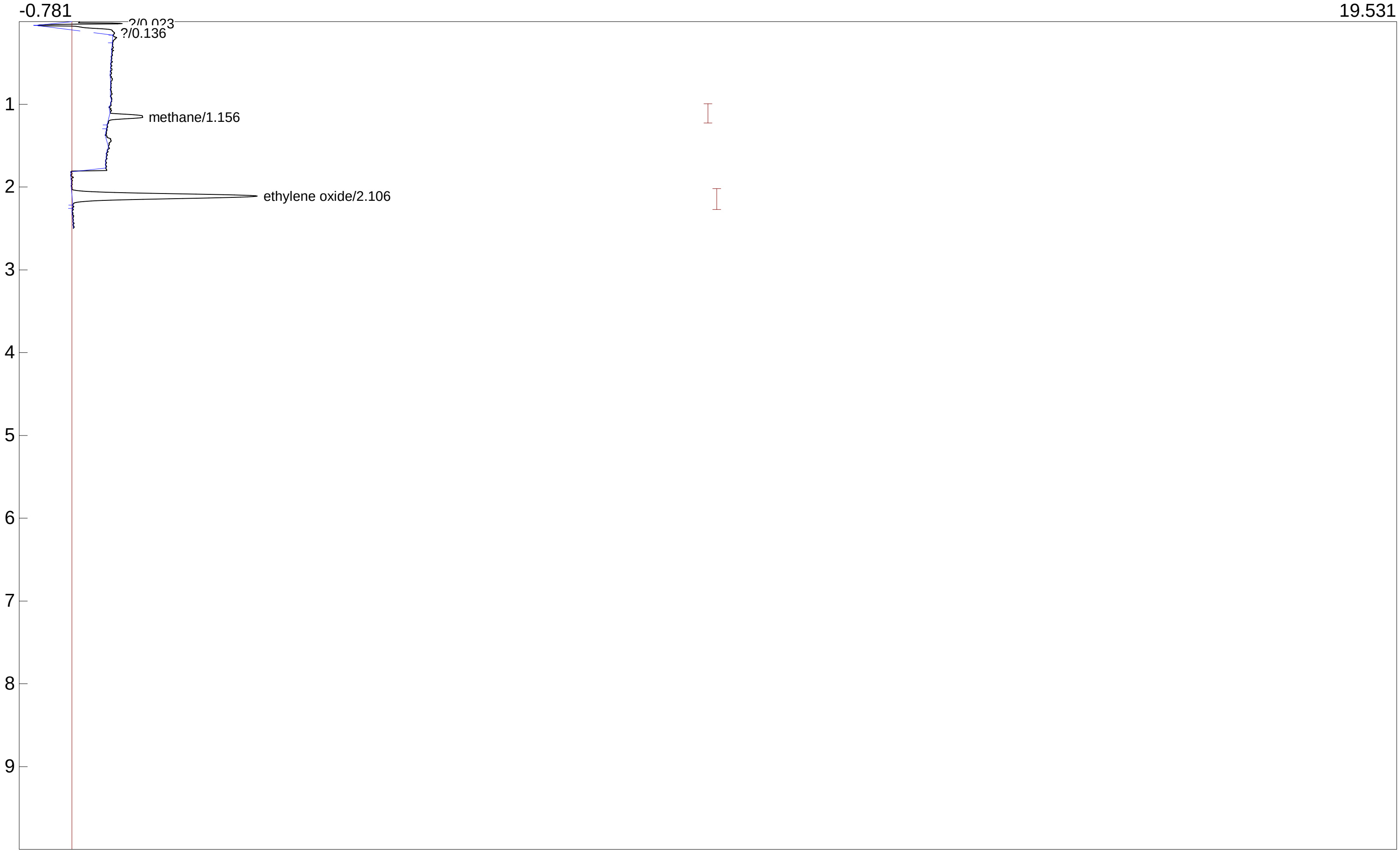
Component	Retention	Area	Height	External	Units
methane	1.163	1.9230	0.584	7.8539	
ethylene oxide	2.113	9.2898	2.298	77.3678	ppm
		11.2128		85.2217	



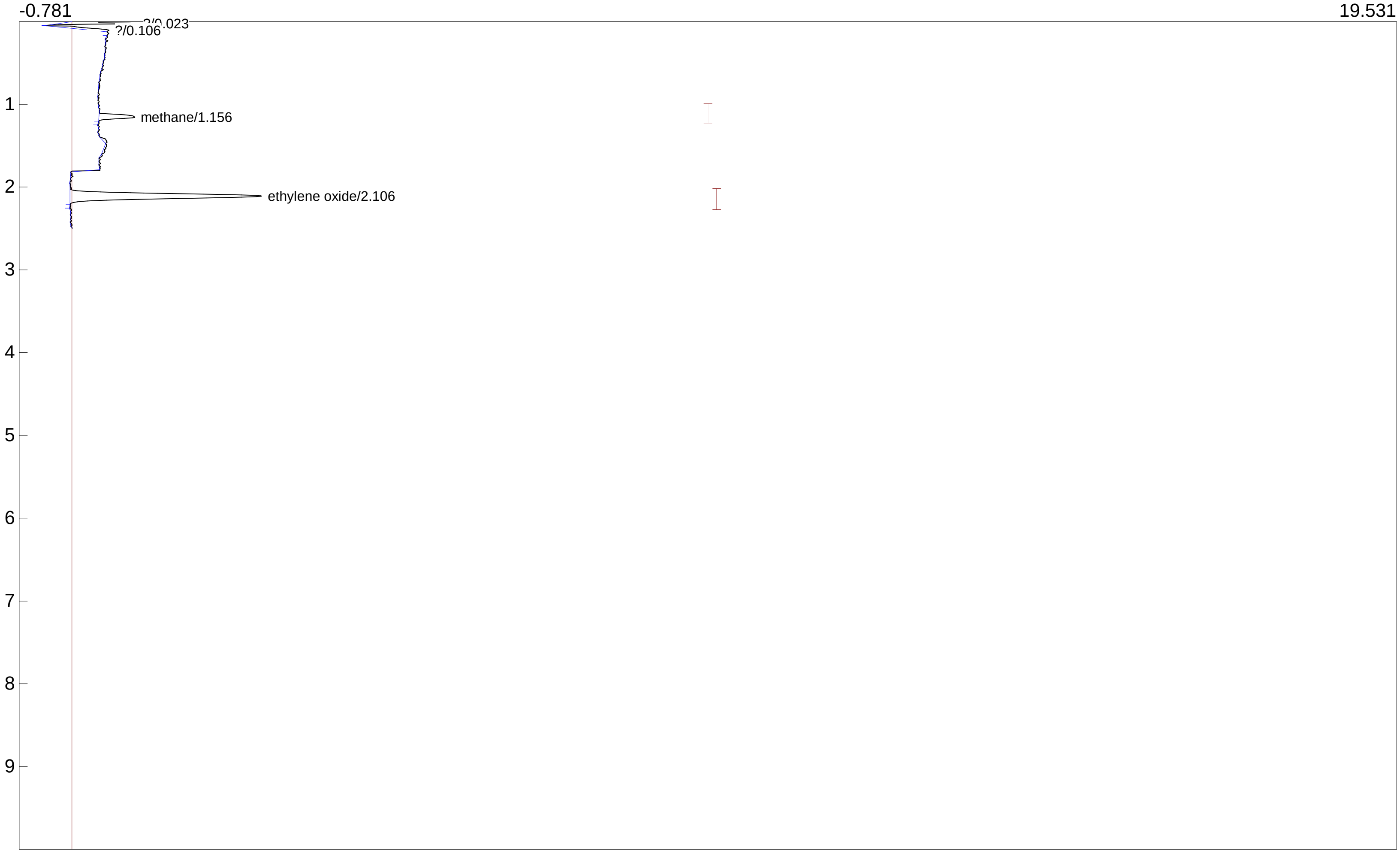
Component	Retention	Area	Height	External	Units
methane	1.153	1.9408	0.595	7.9266	
ethylene oxide	2.103	8.6482	2.118	72.0244	ppm
		10.5890		79.9510	



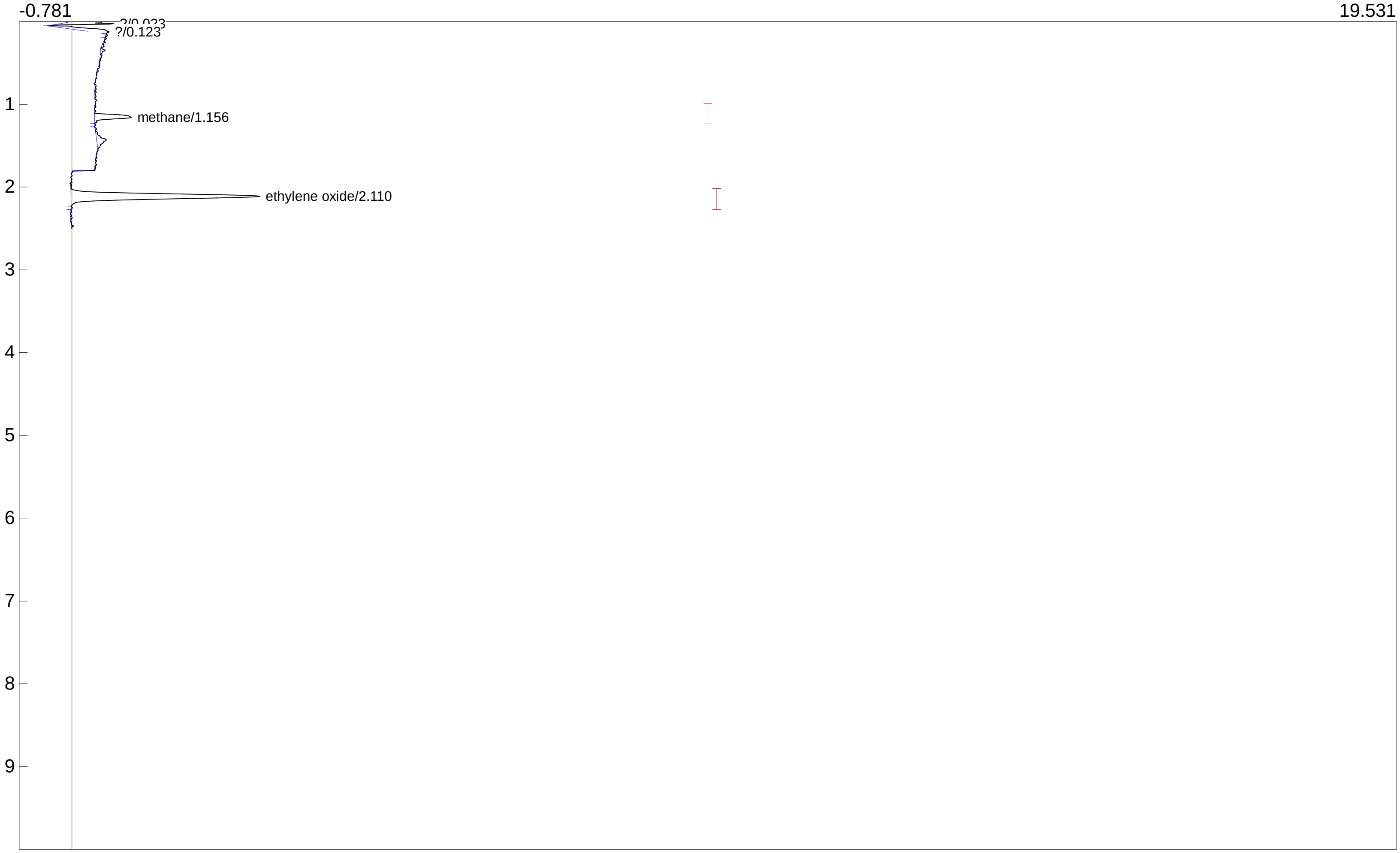
Component	Retention	Area	Height	External	Units
methane	1.156	1.9772	0.609	8.0753	
ethylene oxide	2.106	8.9008	2.199	74.1281	ppm
		10.8780		82.2034	



Component	Retention	Area	Height	External	Units
methane	1.156	1.6504	0.499	0.3370	
ethylene oxide	2.106	11.1194	2.734	4.6303	ppm
		12.7698		4.9673	



Component	Retention	Area	Height	External	Units
methane	1.156	1.7026	0.533	0.3477	
ethylene oxide	2.106	11.4662	2.827	4.7747	ppm
		13.1688		5.1224	



Component	Retention	Area	Height	External	Units
methane	1.156	1.8428	0.545	0.3763	
ethylene oxide	2.110	11.3582	2.784	4.7297	ppm
		13.2010		5.1060	

Component	Retention	Area	Height	External	Units
methane	1.156	3.1102	0.687	0.6351	
ethylene oxide	2.106	23.9203	5.808	9.9607	ppm
		27.0305		10.5958	

Component	Retention	Area	Height	External	Units
methane	1.160	3.2090	0.716	0.6553	
ethylene oxide	2.110	25.7334	6.277	10.7157	ppm
		28.9424		11.3710	

Component	Retention	Area	Height	External	Units
methane	1.156	2.9598	0.674	0.6044	
ethylene oxide	2.106	25.2980	6.151	10.5344	ppm
		28.2578		11.1388	

APPENDIX C

Process Data

Date & Time	Oxidizer Exit Temperature (^oC)
12/20/2017 14:42	160.739
12/20/2017 14:42	160.7319
12/20/2017 14:42	160.7021
12/20/2017 14:42	160.7195
12/20/2017 14:42	160.709
12/20/2017 14:42	160.7093
12/20/2017 14:43	160.6654
12/20/2017 14:43	160.6811
12/20/2017 14:43	160.6778
12/20/2017 14:43	160.6778
12/20/2017 14:43	160.7204
12/20/2017 14:43	160.6459
12/20/2017 14:44	160.6621
12/20/2017 14:44	160.6498
12/20/2017 14:44	160.6744
12/20/2017 14:44	160.6579
12/20/2017 14:44	160.6273
12/20/2017 14:44	160.593
12/20/2017 14:45	160.6658
12/20/2017 14:45	160.6747
12/20/2017 14:45	160.6513
12/20/2017 14:45	160.6895
12/20/2017 14:45	160.6744
12/20/2017 14:45	160.6904
12/20/2017 14:46	160.67
12/20/2017 14:46	160.7117
12/20/2017 14:46	160.7306
12/20/2017 14:46	160.6973
12/20/2017 14:46	160.7448
12/20/2017 14:46	160.6958
12/20/2017 14:47	160.7075
12/20/2017 14:47	160.7901
12/20/2017 14:47	160.7478
12/20/2017 14:47	160.7808
12/20/2017 14:47	160.7964
12/20/2017 14:47	160.8033
12/20/2017 14:48	160.7937
12/20/2017 14:48	160.8992
12/20/2017 14:48	160.8649
12/20/2017 14:48	160.8899
12/20/2017 14:48	160.9172
12/20/2017 14:48	160.9608
12/20/2017 14:49	160.9127

Date & Time	Oxidizer Exit Temperature (°C)
12/20/2017 14:49	160.9509
12/20/2017 14:49	161.0121
12/20/2017 14:49	161.0776
12/20/2017 14:49	160.9899
12/20/2017 14:49	161.1059
12/20/2017 14:50	161.0897
12/20/2017 14:50	161.1074
12/20/2017 14:50	161.1062
12/20/2017 14:50	161.1524
12/20/2017 14:50	161.2297
12/20/2017 14:50	161.1696
12/20/2017 14:51	161.1996
12/20/2017 14:51	161.2077
12/20/2017 14:51	161.239
12/20/2017 14:51	161.2775
12/20/2017 14:51	161.2994
12/20/2017 14:51	161.3423
12/20/2017 14:52	161.303
12/20/2017 14:52	161.2937
12/20/2017 14:52	161.367
12/20/2017 14:52	161.3922
12/20/2017 14:52	161.3913
12/20/2017 14:52	161.4087
12/20/2017 14:53	161.4201
12/20/2017 14:53	161.5157
12/20/2017 14:53	161.4418
12/20/2017 14:53	161.534
12/20/2017 14:53	161.5226
12/20/2017 14:53	161.5508
12/20/2017 14:54	161.5415
12/20/2017 14:54	161.4922
12/20/2017 14:54	161.5686
12/20/2017 14:54	161.6377
12/20/2017 14:54	161.5929
12/20/2017 14:54	161.6512
12/20/2017 14:55	161.6359
12/20/2017 14:55	161.6413
12/20/2017 14:55	161.7077
12/20/2017 14:55	161.692
12/20/2017 14:55	161.7284
12/20/2017 14:55	161.7299
12/20/2017 14:56	161.7062
12/20/2017 14:56	161.799

Date & Time	Oxidizer Exit Temperature (°C)
12/20/2017 14:56	161.7329
12/20/2017 14:56	161.8038
12/20/2017 14:56	161.7425
12/20/2017 14:56	161.8699
12/20/2017 14:57	161.8272
12/20/2017 14:57	161.8311
12/20/2017 14:57	161.8477
12/20/2017 14:57	161.8861
12/20/2017 14:57	161.8933
12/20/2017 14:57	161.8909
12/20/2017 14:58	161.9165
12/20/2017 14:58	161.9134
12/20/2017 14:58	161.9258
12/20/2017 14:58	161.9426
12/20/2017 14:58	161.9405
12/20/2017 14:58	161.9492
12/20/2017 14:59	161.9384
12/20/2017 14:59	161.9372
12/20/2017 14:59	161.9174
12/20/2017 14:59	161.9826
12/20/2017 14:59	161.9537
12/20/2017 14:59	162.0126
12/20/2017 15:00	162.012
12/20/2017 15:00	161.9967
12/20/2017 15:00	162.0138
12/20/2017 15:00	162.076
12/20/2017 15:00	162.0333
12/20/2017 15:00	162.0216
12/20/2017 15:01	162.0361
12/20/2017 15:01	161.997
12/20/2017 15:01	162.0201
12/20/2017 15:01	162.0571
12/20/2017 15:01	162.0426
12/20/2017 15:01	161.9769
12/20/2017 15:02	162.0177
12/20/2017 15:02	161.9823
12/20/2017 15:02	161.9411
12/20/2017 15:02	161.9051
12/20/2017 15:02	161.9886
12/20/2017 15:02	161.9276
12/20/2017 15:03	161.8837
12/20/2017 15:03	161.8612
12/20/2017 15:03	161.8305

Date & Time	Oxidizer Exit Temperature (°C)
12/20/2017 15:03	161.8615
12/20/2017 15:03	161.8393
12/20/2017 15:03	161.7714
12/20/2017 15:04	161.7864
12/20/2017 15:04	161.6842
12/20/2017 15:04	161.6659
12/20/2017 15:04	161.6355
12/20/2017 15:04	161.6419
12/20/2017 15:04	161.5472
12/20/2017 15:05	161.5262
12/20/2017 15:05	161.449
12/20/2017 15:05	161.4385
12/20/2017 15:05	161.4496
12/20/2017 15:05	161.4415
12/20/2017 15:05	161.3595
12/20/2017 15:06	161.33
12/20/2017 15:06	161.3516
12/20/2017 15:06	161.2753
12/20/2017 15:06	161.2654
12/20/2017 15:06	161.166
12/20/2017 15:06	161.1771
12/20/2017 15:07	161.1675
12/20/2017 15:07	161.0939
12/20/2017 15:07	161.087
12/20/2017 15:07	161.0842
12/20/2017 15:07	161.0578
12/20/2017 15:07	160.9641
12/20/2017 15:08	161.0428
12/20/2017 15:08	161.0569
12/20/2017 15:08	161.0203
12/20/2017 15:08	160.9905
12/20/2017 15:08	160.986
12/20/2017 15:08	160.9232
12/20/2017 15:09	160.9896
12/20/2017 15:09	160.989
12/20/2017 15:09	161.0034
12/20/2017 15:09	161.0185
12/20/2017 15:09	161.0155
12/20/2017 15:09	160.9989
12/20/2017 15:10	161.0644
12/20/2017 15:10	161.056
12/20/2017 15:10	161.0888
12/20/2017 15:10	161.1089

Date & Time	Oxidizer Exit Temperature (°C)
12/20/2017 15:10	161.1287
12/20/2017 15:10	161.1627
12/20/2017 15:11	161.2035
12/20/2017 15:11	161.1489
12/20/2017 15:11	161.2288
12/20/2017 15:11	161.2174
12/20/2017 15:11	161.2666
12/20/2017 15:11	161.2639
12/20/2017 15:12	161.2477
12/20/2017 15:12	161.1546
12/20/2017 15:12	161.2156
12/20/2017 15:12	161.2759
12/20/2017 15:12	161.2083
12/20/2017 15:12	161.2201
12/20/2017 15:13	161.2378
12/20/2017 15:13	161.2023
12/20/2017 15:13	161.1954
12/20/2017 15:13	161.2627
12/20/2017 15:13	161.2447
12/20/2017 15:13	161.202
12/20/2017 15:14	161.1999
12/20/2017 15:14	161.1717
12/20/2017 15:14	161.1377
12/20/2017 15:14	161.1753
12/20/2017 15:14	161.1531
12/20/2017 15:14	161.0954
12/20/2017 15:15	161.0317
12/20/2017 15:15	161.0323
12/20/2017 15:15	161.0067
12/20/2017 15:15	160.9839
12/20/2017 15:15	160.9929
12/20/2017 15:15	160.8809
12/20/2017 15:16	160.91
12/20/2017 15:16	160.9076
12/20/2017 15:16	160.8739
12/20/2017 15:16	160.9151
12/20/2017 15:16	160.813
12/20/2017 15:16	160.8166
12/20/2017 15:17	160.7964
12/20/2017 15:17	160.7865
12/20/2017 15:17	160.7829
12/20/2017 15:17	160.7315
12/20/2017 15:17	160.7051

Date & Time	Oxidizer Exit Temperature (°C)
12/20/2017 15:17	160.6498
12/20/2017 15:18	160.7327
12/20/2017 15:18	160.6964
12/20/2017 15:18	160.633
12/20/2017 15:18	160.6931
12/20/2017 15:18	160.6579
12/20/2017 15:18	160.6414
12/20/2017 15:19	160.6219
12/20/2017 15:19	160.6126
12/20/2017 15:19	160.6162
12/20/2017 15:19	160.618
12/20/2017 15:19	160.6327
12/20/2017 15:19	160.5621
12/20/2017 15:20	160.6035
12/20/2017 15:20	160.5954
12/20/2017 15:20	160.5672
12/20/2017 15:20	160.6177
12/20/2017 15:20	160.5858
12/20/2017 15:20	160.6126
12/20/2017 15:21	160.6411
12/20/2017 15:21	160.6303
12/20/2017 15:21	160.6258
12/20/2017 15:21	160.5927
12/20/2017 15:21	160.5846
12/20/2017 15:21	160.5997
12/20/2017 15:22	160.6234
12/20/2017 15:22	160.63
12/20/2017 15:22	160.657
12/20/2017 15:22	160.691
12/20/2017 15:22	160.6685
12/20/2017 15:22	160.6354
12/20/2017 15:23	160.6363
12/20/2017 15:23	160.6811
12/20/2017 15:23	160.7276
12/20/2017 15:23	160.7042
12/20/2017 15:23	160.7526
12/20/2017 15:23	160.7565
12/20/2017 15:24	160.7054
12/20/2017 15:24	160.7643
12/20/2017 15:24	160.7685
12/20/2017 15:24	160.7985
12/20/2017 15:24	160.8397
12/20/2017 15:24	160.7904

Date & Time	Oxidizer Exit Temperature (°C)
12/20/2017 15:25	160.8061
12/20/2017 15:25	160.7946
12/20/2017 15:25	160.846
12/20/2017 15:25	160.8694
12/20/2017 15:25	160.8205
12/20/2017 15:25	160.8784
12/20/2017 15:26	160.8688
12/20/2017 15:26	160.937
12/20/2017 15:26	160.9274
12/20/2017 15:26	160.919
12/20/2017 15:26	160.9448
12/20/2017 15:26	160.9737
12/20/2017 15:27	160.9566
12/20/2017 15:27	160.9848
12/20/2017 15:27	160.9953
12/20/2017 15:27	161.0326
12/20/2017 15:27	161.0383
12/20/2017 15:27	161.0101
12/20/2017 15:28	160.9677
12/20/2017 15:28	161.0677
12/20/2017 15:28	161.1038
12/20/2017 15:28	161.0668
12/20/2017 15:28	161.0572
12/20/2017 15:28	161.0554
12/20/2017 15:29	161.1299
12/20/2017 15:29	161.0452
12/20/2017 15:29	161.1185
12/20/2017 15:29	161.1462
12/20/2017 15:29	161.0864
12/20/2017 15:29	161.1431
12/20/2017 15:30	161.123
12/20/2017 15:30	161.1447
12/20/2017 15:30	161.1326
12/20/2017 15:30	161.1447
12/20/2017 15:30	161.1801
12/20/2017 15:30	161.1705
12/20/2017 15:31	161.1972
12/20/2017 15:31	161.19
12/20/2017 15:31	161.2032
12/20/2017 15:31	161.1278
12/20/2017 15:31	161.2194
12/20/2017 15:31	161.1876
12/20/2017 15:32	161.1744

Date & Time	Oxidizer Exit Temperature (°C)
12/20/2017 15:32	161.2303
12/20/2017 15:32	161.1849
12/20/2017 15:32	161.1711
12/20/2017 15:32	161.1609
12/20/2017 15:32	161.1993
12/20/2017 15:33	161.211
12/20/2017 15:33	161.1669
12/20/2017 15:33	161.223
12/20/2017 15:33	161.2122
12/20/2017 15:33	161.1981
12/20/2017 15:33	161.2519
12/20/2017 15:34	161.245
12/20/2017 15:34	161.2411
12/20/2017 15:34	161.2516
12/20/2017 15:34	161.2092
12/20/2017 15:34	161.2798
12/20/2017 15:34	161.2585
12/20/2017 15:35	161.2252
12/20/2017 15:35	161.2149
12/20/2017 15:35	161.2627
12/20/2017 15:35	161.2237
12/20/2017 15:35	161.233
12/20/2017 15:35	161.2645
12/20/2017 15:36	161.2807
12/20/2017 15:36	161.2303
12/20/2017 15:36	161.2513
12/20/2017 15:36	161.2865
12/20/2017 15:36	161.2967
12/20/2017 15:36	161.2591
12/20/2017 15:37	161.2351
12/20/2017 15:37	161.2255
12/20/2017 15:37	161.2675
12/20/2017 15:37	161.2294
12/20/2017 15:37	161.3048
12/20/2017 15:37	161.2859
12/20/2017 15:38	161.2846
12/20/2017 15:38	161.2582
12/20/2017 15:38	161.2612
12/20/2017 15:38	161.2002
12/20/2017 15:38	161.2279
12/20/2017 15:38	161.2252
12/20/2017 15:39	161.1528
12/20/2017 15:39	161.1561

Date & Time	Oxidizer Exit Temperature (^{o}C)
12/20/2017 15:39	161.2186
12/20/2017 15:39	161.1573
12/20/2017 15:39	161.1753
12/20/2017 15:39	161.1008
12/20/2017 15:40	161.1425
12/20/2017 15:40	161.1906
12/20/2017 15:40	161.2312
12/20/2017 15:40	161.1735
12/20/2017 15:40	161.1837
12/20/2017 15:40	161.1332
12/20/2017 15:41	161.0936
12/20/2017 15:41	161.0768
12/20/2017 15:41	161.1035
12/20/2017 15:41	161.1044
12/20/2017 15:41	161.1293
12/20/2017 15:41	161.1227
Run 1 Average	**161.1660**
12/20/2017 15:42	161.0939
12/20/2017 15:42	161.1257
12/20/2017 15:42	161.1413
12/20/2017 15:42	161.1738
12/20/2017 15:42	161.1266
12/20/2017 15:42	161.1119
12/20/2017 15:43	161.068
12/20/2017 15:43	161.0713
12/20/2017 15:43	161.138
12/20/2017 15:43	161.0945
12/20/2017 15:43	161.1038
12/20/2017 15:43	161.2047
12/20/2017 15:44	161.1266
12/20/2017 15:44	161.1437
12/20/2017 15:44	161.1101
12/20/2017 15:44	161.0731
12/20/2017 15:44	161.1245
12/20/2017 15:44	161.1035
12/20/2017 15:45	161.1516
12/20/2017 15:45	161.1305
12/20/2017 15:45	161.1116
12/20/2017 15:45	161.0753
12/20/2017 15:45	161.0461
12/20/2017 15:45	161.0055
12/20/2017 15:46	160.9698
12/20/2017 15:46	160.9728

Date & Time	Oxidizer Exit Temperature (°C)
12/20/2017 15:46	160.8977
12/20/2017 15:46	160.9698
12/20/2017 15:46	160.9124
12/20/2017 15:46	160.8613
12/20/2017 15:47	160.8577
12/20/2017 15:47	160.7661
12/20/2017 15:47	160.7249
12/20/2017 15:47	160.6949
12/20/2017 15:47	160.697
12/20/2017 15:47	160.6312
12/20/2017 15:48	160.6234
12/20/2017 15:48	160.572
12/20/2017 15:48	160.575
12/20/2017 15:48	160.5759
12/20/2017 15:48	160.4867
12/20/2017 15:48	160.4353
12/20/2017 15:49	160.4386
12/20/2017 15:49	160.4419
12/20/2017 15:49	160.383
12/20/2017 15:49	160.371
12/20/2017 15:49	160.3599
12/20/2017 15:49	160.3785
12/20/2017 15:50	160.295
12/20/2017 15:50	160.3043
12/20/2017 15:50	160.3199
12/20/2017 15:50	160.3398
12/20/2017 15:50	160.3211
12/20/2017 15:50	160.2914
12/20/2017 15:51	160.317
12/20/2017 15:51	160.3034
12/20/2017 15:51	160.2668
12/20/2017 15:51	160.2614
12/20/2017 15:51	160.3136
12/20/2017 15:51	160.2812
12/20/2017 15:52	160.332
12/20/2017 15:52	160.3692
12/20/2017 15:52	160.3085
12/20/2017 15:52	160.3238
12/20/2017 15:52	160.2923
12/20/2017 15:52	160.3602
12/20/2017 15:53	160.4344
12/20/2017 15:53	160.4485
12/20/2017 15:53	160.4026

Date & Time	Oxidizer Exit Temperature (^oC)
12/20/2017 15:53	160.4266
12/20/2017 15:53	160.4155
12/20/2017 15:53	160.3827
12/20/2017 15:54	160.4164
12/20/2017 15:54	160.4954
12/20/2017 15:54	160.4296
12/20/2017 15:54	160.3731
12/20/2017 15:54	160.4059
12/20/2017 15:54	160.4467
12/20/2017 15:55	160.4194
12/20/2017 15:55	160.3662
12/20/2017 15:55	160.4717
12/20/2017 15:55	160.3836
12/20/2017 15:55	160.3996
12/20/2017 15:55	160.4311
12/20/2017 15:56	160.4521
12/20/2017 15:56	160.3734
12/20/2017 15:56	160.3194
12/20/2017 15:56	160.3593
12/20/2017 15:56	160.3208
12/20/2017 15:56	160.3172
12/20/2017 15:57	160.3287
12/20/2017 15:57	160.2938
12/20/2017 15:57	160.3016
12/20/2017 15:57	160.2869
12/20/2017 15:57	160.2469
12/20/2017 15:57	160.2049
12/20/2017 15:58	160.2683
12/20/2017 15:58	160.2542
12/20/2017 15:58	160.2605
12/20/2017 15:58	160.1893
12/20/2017 15:58	160.1168
12/20/2017 15:58	160.1967
12/20/2017 15:59	160.1069
12/20/2017 15:59	160.1808
12/20/2017 15:59	160.2163
12/20/2017 15:59	160.1292
12/20/2017 15:59	160.0982
12/20/2017 15:59	160.0715
12/20/2017 16:00	160.1193
12/20/2017 16:00	160.1177
12/20/2017 16:00	160.1184
12/20/2017 16:00	160.1051

Date & Time	Oxidizer Exit Temperature (°C)
12/20/2017 16:00	160.0982
12/20/2017 16:00	160.0706
12/20/2017 16:01	160.0958
12/20/2017 16:01	160.0679
12/20/2017 16:01	160.0997
12/20/2017 16:01	160.125
12/20/2017 16:01	160.1358
12/20/2017 16:01	160.0829
12/20/2017 16:02	160.0859
12/20/2017 16:02	160.1238
12/20/2017 16:02	160.1003
12/20/2017 16:02	160.0913
12/20/2017 16:02	160.0925
12/20/2017 16:02	160.1234
12/20/2017 16:03	160.1021
12/20/2017 16:03	160.0967
12/20/2017 16:03	160.1769
12/20/2017 16:03	160.1511
12/20/2017 16:03	160.1421
12/20/2017 16:03	160.1184
12/20/2017 16:04	160.091
12/20/2017 16:04	160.1277
12/20/2017 16:04	160.155
12/20/2017 16:04	160.158
12/20/2017 16:04	160.2094
12/20/2017 16:04	160.1745
12/20/2017 16:05	160.1664
12/20/2017 16:05	160.1511
12/20/2017 16:05	160.1872
12/20/2017 16:05	160.1907
12/20/2017 16:05	160.1869
12/20/2017 16:05	160.2376
12/20/2017 16:06	160.2361
12/20/2017 16:06	160.2968
12/20/2017 16:06	160.2848
12/20/2017 16:06	160.2974
12/20/2017 16:06	160.2959
12/20/2017 16:06	160.2767
12/20/2017 16:07	160.356
12/20/2017 16:07	160.3692
12/20/2017 16:07	160.3755
12/20/2017 16:07	160.3785
12/20/2017 16:07	160.3776

Date & Time	Oxidizer Exit Temperature (°C)
12/20/2017 16:07	160.3957
12/20/2017 16:08	160.4741
12/20/2017 16:08	160.4122
12/20/2017 16:08	160.4191
12/20/2017 16:08	160.4488
12/20/2017 16:08	160.4383
12/20/2017 16:08	160.4921
12/20/2017 16:09	160.5143
12/20/2017 16:09	160.5405
12/20/2017 16:09	160.5648
12/20/2017 16:09	160.5417
12/20/2017 16:09	160.5411
12/20/2017 16:09	160.5128
12/20/2017 16:10	160.5939
12/20/2017 16:10	160.5879
12/20/2017 16:10	160.6531
12/20/2017 16:10	160.5961
12/20/2017 16:10	160.5687
12/20/2017 16:10	160.5798
12/20/2017 16:11	160.5615
12/20/2017 16:11	160.6351
12/20/2017 16:11	160.5798
12/20/2017 16:11	160.6408
12/20/2017 16:11	160.5831
12/20/2017 16:11	160.5987
12/20/2017 16:12	160.6399
12/20/2017 16:12	160.5747
12/20/2017 16:12	160.6387
12/20/2017 16:12	160.6372
12/20/2017 16:12	160.6462
12/20/2017 16:12	160.6895
12/20/2017 16:13	160.7132
12/20/2017 16:13	160.648
12/20/2017 16:13	160.6645
12/20/2017 16:13	160.6459
12/20/2017 16:13	160.6883
12/20/2017 16:13	160.7367
12/20/2017 16:14	160.645
12/20/2017 16:14	160.651
12/20/2017 16:14	160.7033
12/20/2017 16:14	160.6621
12/20/2017 16:14	160.6676
12/20/2017 16:14	160.6781

Date & Time	Oxidizer Exit Temperature (^{o}C)
12/20/2017 16:15	160.6763
12/20/2017 16:15	160.7096
12/20/2017 16:15	160.6507
12/20/2017 16:15	160.6829
12/20/2017 16:15	160.6381
12/20/2017 16:15	160.6357
12/20/2017 16:16	160.6597
12/20/2017 16:16	160.6399
12/20/2017 16:16	160.6648
12/20/2017 16:16	160.663
12/20/2017 16:16	160.6327
12/20/2017 16:16	160.6483
12/20/2017 16:17	160.6567
12/20/2017 16:17	160.6693
12/20/2017 16:17	160.6579
12/20/2017 16:17	160.6477
12/20/2017 16:17	160.6459
12/20/2017 16:17	160.6645
12/20/2017 16:18	160.7048
12/20/2017 16:18	160.6964
12/20/2017 16:18	160.7448
12/20/2017 16:18	160.7102
12/20/2017 16:18	160.7475
12/20/2017 16:18	160.7415
12/20/2017 16:19	160.6994
12/20/2017 16:19	160.7493
12/20/2017 16:19	160.727
12/20/2017 16:19	160.7745
12/20/2017 16:19	160.6901
12/20/2017 16:19	160.7306
12/20/2017 16:20	160.7075
12/20/2017 16:20	160.7631
12/20/2017 16:20	160.7577
12/20/2017 16:20	160.7426
12/20/2017 16:20	160.6988
12/20/2017 16:20	160.7928
12/20/2017 16:21	160.8205
12/20/2017 16:21	160.7289
12/20/2017 16:21	160.758
12/20/2017 16:21	160.7592
12/20/2017 16:21	160.8301
12/20/2017 16:21	160.8079
12/20/2017 16:22	160.7944

Date & Time	Oxidizer Exit Temperature (°C)
12/20/2017 16:22	160.8767
12/20/2017 16:22	160.7904
12/20/2017 16:22	160.8072
12/20/2017 16:22	160.8075
12/20/2017 16:22	160.8301
12/20/2017 16:23	160.803
12/20/2017 16:23	160.758
12/20/2017 16:23	160.7931
12/20/2017 16:23	160.7541
12/20/2017 16:23	160.7931
12/20/2017 16:23	160.8075
12/20/2017 16:24	160.7499
12/20/2017 16:24	160.7201
12/20/2017 16:24	160.6943
12/20/2017 16:24	160.737
12/20/2017 16:24	160.7033
12/20/2017 16:24	160.7598
12/20/2017 16:25	160.6796
12/20/2017 16:25	160.7523
12/20/2017 16:25	160.7379
12/20/2017 16:25	160.6811
12/20/2017 16:25	160.6925
12/20/2017 16:25	160.6961
12/20/2017 16:26	160.7583
12/20/2017 16:26	160.7385
12/20/2017 16:26	160.6008
12/20/2017 16:26	160.6291
12/20/2017 16:26	160.6195
12/20/2017 16:26	160.6612
12/20/2017 16:27	160.6555
12/20/2017 16:27	160.6282
12/20/2017 16:27	160.6018
12/20/2017 16:27	160.5666
12/20/2017 16:27	160.5645
12/20/2017 16:27	160.505
12/20/2017 16:28	160.584
12/20/2017 16:28	160.5185
12/20/2017 16:28	160.4395
12/20/2017 16:28	160.42
12/20/2017 16:28	160.3737
12/20/2017 16:28	160.3761
12/20/2017 16:29	160.3275
12/20/2017 16:29	160.2689

Date & Time	Oxidizer Exit Temperature (°C)
12/20/2017 16:29	160.2346
12/20/2017 16:29	160.2653
12/20/2017 16:29	160.2145
12/20/2017 16:29	160.1382
12/20/2017 16:30	160.1547
12/20/2017 16:30	160.1412
12/20/2017 16:30	160.0072
12/20/2017 16:30	160.0087
12/20/2017 16:30	159.9747
12/20/2017 16:30	159.9126
12/20/2017 16:31	159.9164
12/20/2017 16:31	159.8945
12/20/2017 16:31	159.911
12/20/2017 16:31	159.9288
12/20/2017 16:31	159.8164
12/20/2017 16:31	159.8251
12/20/2017 16:32	159.8179
12/20/2017 16:32	159.7804
12/20/2017 16:32	159.7248
12/20/2017 16:32	159.7611
12/20/2017 16:32	159.7692
12/20/2017 16:32	159.6869
12/20/2017 16:33	159.7311
12/20/2017 16:33	159.738
12/20/2017 16:33	159.7092
12/20/2017 16:33	159.7638
12/20/2017 16:33	159.7416
12/20/2017 16:33	159.8368
12/20/2017 16:34	159.7735
12/20/2017 16:34	159.7665
12/20/2017 16:34	159.8531
12/20/2017 16:34	159.8579
12/20/2017 16:34	159.9216
12/20/2017 16:34	159.8879
12/20/2017 16:35	159.9333
12/20/2017 16:35	159.9282
12/20/2017 16:35	159.9348
12/20/2017 16:35	160.0027
12/20/2017 16:35	159.9309
12/20/2017 16:35	160.0147
12/20/2017 16:36	160.0484
12/20/2017 16:36	160.0348
12/20/2017 16:36	160.0171

Date & Time	Oxidizer Exit Temperature (^{o}C)
12/20/2017 16:36	160.0429
12/20/2017 16:36	160.079
12/20/2017 16:36	160.1057
12/20/2017 16:37	160.082
12/20/2017 16:37	160.0532
12/20/2017 16:37	160.1565
12/20/2017 16:37	160.1114
12/20/2017 16:37	160.0898
12/20/2017 16:37	160.1211
12/20/2017 16:38	160.1141
12/20/2017 16:38	160.0748
12/20/2017 16:38	160.1316
12/20/2017 16:38	160.067
12/20/2017 16:38	160.0378
12/20/2017 16:38	160.0565
12/20/2017 16:39	160.0384
12/20/2017 16:39	159.9925
12/20/2017 16:39	160.0459
12/20/2017 16:39	160.0423
12/20/2017 16:39	160.0273
12/20/2017 16:39	159.9753
12/20/2017 16:40	159.9822
12/20/2017 16:40	159.9438
12/20/2017 16:40	159.9213
12/20/2017 16:40	159.9762
12/20/2017 16:40	159.9147
12/20/2017 16:40	159.9038
12/20/2017 16:41	159.9134
12/20/2017 16:41	159.848
12/20/2017 16:41	159.927
12/20/2017 16:41	159.8422
12/20/2017 16:41	159.8431
12/20/2017 16:41	159.7641
12/20/2017 16:42	159.8417
12/20/2017 16:42	159.7176
12/20/2017 16:42	159.6893
12/20/2017 16:42	159.7329
12/20/2017 16:42	159.665
12/20/2017 16:42	159.6421
12/20/2017 16:43	159.549
12/20/2017 16:43	159.5794
12/20/2017 16:43	159.5541
12/20/2017 16:43	159.5334

Date & Time	Oxidizer Exit Temperature (°C)
12/20/2017 16:43	159.4868
12/20/2017 16:43	159.4141
Run 2 Average	**160.3672**
12/20/2017 16:44	159.4006
12/20/2017 16:44	159.4511
12/20/2017 16:44	159.3396
12/20/2017 16:44	159.3766
12/20/2017 16:44	159.3372
12/20/2017 16:44	159.2576
12/20/2017 16:45	159.2858
12/20/2017 16:45	159.2666
12/20/2017 16:45	159.141
12/20/2017 16:45	159.1759
12/20/2017 16:45	159.1942
12/20/2017 16:45	159.1774
12/20/2017 16:46	159.126
12/20/2017 16:46	159.1269
12/20/2017 16:46	159.1359
12/20/2017 16:46	159.1137
12/20/2017 16:46	159.1654
12/20/2017 16:46	159.1431
12/20/2017 16:47	159.1422
12/20/2017 16:47	159.1092
12/20/2017 16:47	159.1113
12/20/2017 16:47	159.0803
12/20/2017 16:47	159.0713
12/20/2017 16:47	159.0927
12/20/2017 16:48	159.1786
12/20/2017 16:48	159.172
12/20/2017 16:48	159.2047
12/20/2017 16:48	159.2152
12/20/2017 16:48	159.2393
12/20/2017 16:48	159.2792
12/20/2017 16:49	159.3946
12/20/2017 16:49	159.3528
12/20/2017 16:49	159.3264
12/20/2017 16:49	159.421
12/20/2017 16:49	159.4478
12/20/2017 16:49	159.4706
12/20/2017 16:50	159.5268
12/20/2017 16:50	159.522
12/20/2017 16:50	159.577
12/20/2017 16:50	159.5628

Date & Time	Oxidizer Exit Temperature (°C)
12/20/2017 16:50	159.6208
12/20/2017 16:50	159.6497
12/20/2017 16:51	159.6737
12/20/2017 16:51	159.7194
12/20/2017 16:51	159.72
12/20/2017 16:51	159.7299
12/20/2017 16:51	159.7095
12/20/2017 16:51	159.7515
12/20/2017 16:52	159.8113
12/20/2017 16:52	159.7422
12/20/2017 16:52	159.8056
12/20/2017 16:52	159.7837
12/20/2017 16:52	159.8092
12/20/2017 16:52	159.8558
12/20/2017 16:53	159.8447
12/20/2017 16:53	159.8519
12/20/2017 16:53	159.8329
12/20/2017 16:53	159.7942
12/20/2017 16:53	159.7882
12/20/2017 16:53	159.8125
12/20/2017 16:54	159.8092
12/20/2017 16:54	159.7969
12/20/2017 16:54	159.7912
12/20/2017 16:54	159.8188
12/20/2017 16:54	159.7777
12/20/2017 16:54	159.7569
12/20/2017 16:55	159.7822
12/20/2017 16:55	159.7954
12/20/2017 16:55	159.7431
12/20/2017 16:55	159.7657
12/20/2017 16:55	159.7398
12/20/2017 16:55	159.6818
12/20/2017 16:56	159.689
12/20/2017 16:56	159.6752
12/20/2017 16:56	159.7374
12/20/2017 16:56	159.7386
12/20/2017 16:56	159.6824
12/20/2017 16:56	159.6926
12/20/2017 16:57	159.6767
12/20/2017 16:57	159.6358
12/20/2017 16:57	159.6689
12/20/2017 16:57	159.6548
12/20/2017 16:57	159.6112

Date & Time	Oxidizer Exit Temperature (°C)
12/20/2017 16:57	159.6142
12/20/2017 16:58	159.6286
12/20/2017 16:58	159.6398
12/20/2017 16:58	159.6175
12/20/2017 16:58	159.6238
12/20/2017 16:58	159.6238
12/20/2017 16:58	159.613
12/20/2017 16:59	159.6377
12/20/2017 16:59	159.6548
12/20/2017 16:59	159.5655
12/20/2017 16:59	159.5751
12/20/2017 16:59	159.5896
12/20/2017 16:59	159.6241
12/20/2017 17:00	159.5514
12/20/2017 17:00	159.5971
12/20/2017 17:00	159.6638
12/20/2017 17:00	159.6178
12/20/2017 17:00	159.6214
12/20/2017 17:00	159.6022
12/20/2017 17:01	159.6554
12/20/2017 17:01	159.665
12/20/2017 17:01	159.6448
12/20/2017 17:01	159.6545
12/20/2017 17:01	159.6842
12/20/2017 17:01	159.6533
12/20/2017 17:02	159.6806
12/20/2017 17:02	159.659
12/20/2017 17:02	159.6485
12/20/2017 17:02	159.6512
12/20/2017 17:02	159.6316
12/20/2017 17:02	159.6671
12/20/2017 17:03	159.6404
12/20/2017 17:03	159.6139
12/20/2017 17:03	159.668
12/20/2017 17:03	159.6611
12/20/2017 17:03	159.6698
12/20/2017 17:03	159.7389
12/20/2017 17:04	159.68
12/20/2017 17:04	159.7392
12/20/2017 17:04	159.6226
12/20/2017 17:04	159.7107
12/20/2017 17:04	159.7242
12/20/2017 17:04	159.7374

Date & Time	Oxidizer Exit Temperature (°C)
12/20/2017 17:05	159.7013
12/20/2017 17:05	159.7284
12/20/2017 17:05	159.7176
12/20/2017 17:05	159.7173
12/20/2017 17:05	159.7395
12/20/2017 17:05	159.7572
12/20/2017 17:06	159.7629
12/20/2017 17:06	159.7398
12/20/2017 17:06	159.8017
12/20/2017 17:06	159.7638
12/20/2017 17:06	159.7843
12/20/2017 17:06	159.7665
12/20/2017 17:07	159.7425
12/20/2017 17:07	159.7789
12/20/2017 17:07	159.8354
12/20/2017 17:07	159.7936
12/20/2017 17:07	159.8954
12/20/2017 17:07	159.8711
12/20/2017 17:08	159.9032
12/20/2017 17:08	159.8489
12/20/2017 17:08	159.8323
12/20/2017 17:08	159.8594
12/20/2017 17:08	159.9038
12/20/2017 17:08	159.8573
12/20/2017 17:09	159.9261
12/20/2017 17:09	159.9168
12/20/2017 17:09	159.8666
12/20/2017 17:09	159.89
12/20/2017 17:09	159.854
12/20/2017 17:09	159.9201
12/20/2017 17:10	159.9171
12/20/2017 17:10	159.9516
12/20/2017 17:10	159.9423
12/20/2017 17:10	159.8963
12/20/2017 17:10	159.8969
12/20/2017 17:10	159.9399
12/20/2017 17:11	159.9537
12/20/2017 17:11	159.9231
12/20/2017 17:11	159.9339
12/20/2017 17:11	159.945
12/20/2017 17:11	159.9552
12/20/2017 17:11	159.9348
12/20/2017 17:12	160.0108

Date & Time	Oxidizer Exit Temperature (°C)
12/20/2017 17:12	159.9639
12/20/2017 17:12	159.8711
12/20/2017 17:12	159.9411
12/20/2017 17:12	159.9591
12/20/2017 17:12	159.9174
12/20/2017 17:13	159.9886
12/20/2017 17:13	159.9351
12/20/2017 17:13	159.8819
12/20/2017 17:13	159.8945
12/20/2017 17:13	159.9441
12/20/2017 17:13	159.9186
12/20/2017 17:14	159.914
12/20/2017 17:14	159.9186
12/20/2017 17:14	159.927
12/20/2017 17:14	159.9492
12/20/2017 17:14	159.8726
12/20/2017 17:14	159.8942
12/20/2017 17:15	159.9441
12/20/2017 17:15	159.9609
12/20/2017 17:15	159.9402
12/20/2017 17:15	159.908
12/20/2017 17:15	159.909
12/20/2017 17:15	159.9684
12/20/2017 17:16	159.9228
12/20/2017 17:16	159.9949
12/20/2017 17:16	159.9099
12/20/2017 17:16	159.9077
12/20/2017 17:16	159.9606
12/20/2017 17:16	159.9501
12/20/2017 17:17	159.9288
12/20/2017 17:17	159.9309
12/20/2017 17:17	159.9741
12/20/2017 17:17	159.9312
12/20/2017 17:17	159.9147
12/20/2017 17:17	159.8501
12/20/2017 17:18	159.9075
12/20/2017 17:18	159.866
12/20/2017 17:18	159.8582
12/20/2017 17:18	159.8218
12/20/2017 17:18	159.8359
12/20/2017 17:18	159.8422
12/20/2017 17:19	159.842
12/20/2017 17:19	159.8633

Date & Time	Oxidizer Exit Temperature (°C)
12/20/2017 17:19	159.8437
12/20/2017 17:19	159.8666
12/20/2017 17:19	159.8245
12/20/2017 17:19	159.8227
12/20/2017 17:20	159.7951
12/20/2017 17:20	159.7918
12/20/2017 17:20	159.7461
12/20/2017 17:20	159.7136
12/20/2017 17:20	159.7554
12/20/2017 17:20	159.7386
12/20/2017 17:21	159.765
12/20/2017 17:21	159.7804
12/20/2017 17:21	159.7125
12/20/2017 17:21	159.7443
12/20/2017 17:21	159.7446
12/20/2017 17:21	159.8125
12/20/2017 17:22	159.756
12/20/2017 17:22	159.7209
12/20/2017 17:22	159.7221
12/20/2017 17:22	159.7554
12/20/2017 17:22	159.7149
12/20/2017 17:22	159.738
12/20/2017 17:23	159.7049
12/20/2017 17:23	159.7128
12/20/2017 17:23	159.7236
12/20/2017 17:23	159.7362
12/20/2017 17:23	159.7602
12/20/2017 17:23	159.7269
12/20/2017 17:24	159.7548
12/20/2017 17:24	159.7825
12/20/2017 17:24	159.796
12/20/2017 17:24	159.7816
12/20/2017 17:24	159.7801
12/20/2017 17:24	159.7293
12/20/2017 17:25	159.7116
12/20/2017 17:25	159.701
12/20/2017 17:25	159.7771
12/20/2017 17:25	159.7629
12/20/2017 17:25	159.8116
12/20/2017 17:25	159.7978
12/20/2017 17:26	159.7157
12/20/2017 17:26	159.7533
12/20/2017 17:26	159.7657

Date & Time	Oxidizer Exit Temperature (^oC)
12/20/2017 17:26	159.7563
12/20/2017 17:26	159.7554
12/20/2017 17:26	159.7338
12/20/2017 17:27	159.7176
12/20/2017 17:27	159.714
12/20/2017 17:27	159.7554
12/20/2017 17:27	159.7293
12/20/2017 17:27	159.7179
12/20/2017 17:27	159.7389
12/20/2017 17:28	159.7215
12/20/2017 17:28	159.6887
12/20/2017 17:28	159.7557
12/20/2017 17:28	159.7395
12/20/2017 17:28	159.7136
12/20/2017 17:28	159.72
12/20/2017 17:29	159.711
12/20/2017 17:29	159.6881
12/20/2017 17:29	159.671
12/20/2017 17:29	159.6404
12/20/2017 17:29	159.7095
12/20/2017 17:29	159.6659
12/20/2017 17:30	159.6256
12/20/2017 17:30	159.6999
12/20/2017 17:30	159.6602
12/20/2017 17:30	159.6698
12/20/2017 17:30	159.6605
12/20/2017 17:30	159.6617
12/20/2017 17:31	159.7107
12/20/2017 17:31	159.6304
12/20/2017 17:31	159.6662
12/20/2017 17:31	159.7308
12/20/2017 17:31	159.6641
12/20/2017 17:31	159.7605
12/20/2017 17:32	159.668
12/20/2017 17:32	159.6398
12/20/2017 17:32	159.6229
12/20/2017 17:32	159.6635
12/20/2017 17:32	159.5761
12/20/2017 17:32	159.589
12/20/2017 17:33	159.61
12/20/2017 17:33	159.6295
12/20/2017 17:33	159.616
12/20/2017 17:33	159.6304

Date & Time	Oxidizer Exit Temperature (°C)
12/20/2017 17:33	159.6214
12/20/2017 17:33	159.6364
12/20/2017 17:34	159.6569
12/20/2017 17:34	159.662
12/20/2017 17:34	159.6208
12/20/2017 17:34	159.6016
12/20/2017 17:34	159.5932
12/20/2017 17:34	159.6079
12/20/2017 17:35	159.6058
12/20/2017 17:35	159.5532
12/20/2017 17:35	159.6343
12/20/2017 17:35	159.601
12/20/2017 17:35	159.5905
12/20/2017 17:35	159.546
12/20/2017 17:36	159.5124
12/20/2017 17:36	159.5409
12/20/2017 17:36	159.5349
12/20/2017 17:36	159.5592
12/20/2017 17:36	159.6034
12/20/2017 17:36	159.5039
12/20/2017 17:37	159.5391
12/20/2017 17:37	159.5367
12/20/2017 17:37	159.5352
12/20/2017 17:37	159.5917
12/20/2017 17:37	159.561
12/20/2017 17:37	159.5271
12/20/2017 17:38	159.5709
12/20/2017 17:38	159.5421
12/20/2017 17:38	159.5112
12/20/2017 17:38	159.4958
12/20/2017 17:38	159.5003
12/20/2017 17:38	159.4709
12/20/2017 17:39	159.4688
12/20/2017 17:39	159.4343
12/20/2017 17:39	159.4724
12/20/2017 17:39	159.4619
12/20/2017 17:39	159.4574
12/20/2017 17:39	159.4916
12/20/2017 17:40	159.4781
12/20/2017 17:40	159.4727
12/20/2017 17:40	159.4108
12/20/2017 17:40	159.4913
12/20/2017 17:40	159.5151

Date & Time	Oxidizer Exit Temperature (°C)
12/20/2017 17:40	159.5196
12/20/2017 17:41	159.4222
12/20/2017 17:41	159.4715
12/20/2017 17:41	159.5217
12/20/2017 17:41	159.5019
12/20/2017 17:41	159.5704
12/20/2017 17:41	159.4649
12/20/2017 17:42	159.5145
12/20/2017 17:42	159.4907
12/20/2017 17:42	159.4562
12/20/2017 17:42	159.4556
12/20/2017 17:42	159.5094
12/20/2017 17:42	159.5151
12/20/2017 17:43	159.503
12/20/2017 17:43	159.5766
12/20/2017 17:43	159.5655
12/20/2017 17:43	159.5643
12/20/2017 17:43	159.6082
12/20/2017 17:43	159.5472
12/20/2017 17:44	159.5803
12/20/2017 17:44	159.5803
12/20/2017 17:44	159.5956
12/20/2017 17:44	159.5845
12/20/2017 17:44	159.5887
12/20/2017 17:44	159.5848
12/20/2017 17:45	159.58
12/20/2017 17:45	159.5914
12/20/2017 17:45	159.5836
12/20/2017 17:45	159.6301
12/20/2017 17:45	159.5568
12/20/2017 17:45	159.5547
12/20/2017 17:46	159.552
12/20/2017 17:46	159.5878
12/20/2017 17:46	159.598
12/20/2017 17:46	159.5748
12/20/2017 17:46	159.6001
12/20/2017 17:46	159.5968
12/20/2017 17:47	159.5953
12/20/2017 17:47	159.5589
12/20/2017 17:47	159.5349
12/20/2017 17:47	159.5737
12/20/2017 17:47	159.5731
12/20/2017 17:47	159.5839

Date & Time	Oxidizer Exit Temperature (°C)
Run 3 Average	**159.6967**

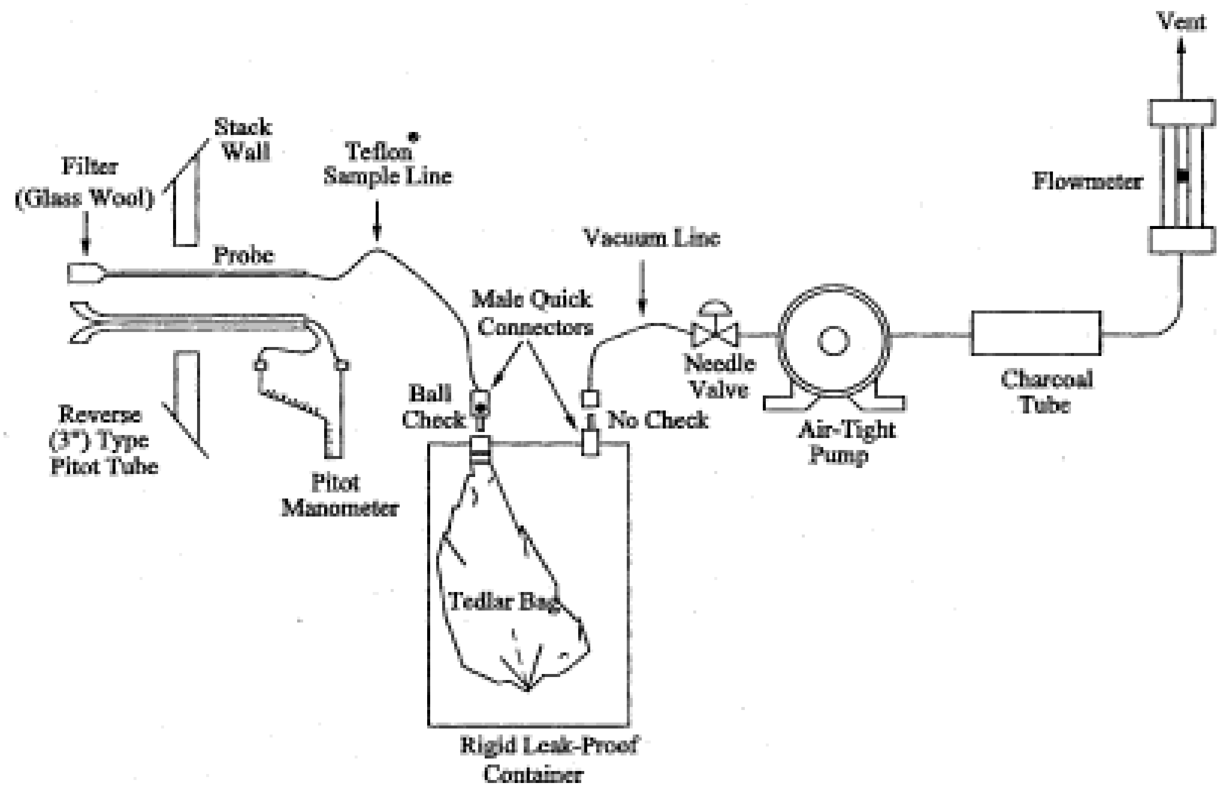
Appendix D

Test Method Descriptions

SUMMARY

Sample gas is collected in a Tedlar bag at a constant rate and the bag sample is analyzed by gas chromatography for volatile organic compounds. A sampling train schematic is shown below and photographs are attached.

SAMPLING TRAIN



Sampling Components:

- Glass or stainless steel probe of sufficient length to reach required sample points.
- An in-stack or out-of-stack filter made of material which is non-reactive to the sample gas. The filter is not required where no significant particulate matter is present.
- Sample line made of Teflon or other material that does not absorb or alter the sample gas.
- Rigid gas tight container with compression type fittings
- Flexible bags constructed of Tedlar or other inert material
- Gas flow meter or critical orifice flow controller
- Leak-free pump constructed of non-reactive material to pull sample through the system at a sufficient rate to minimize the response time.

Analytical Components

- SRI Inc. Model 8610C gas chromatograph, laptop computer with Peaksimple software and USB cable
- Restek MXT-1 60 meter steel capillary column (test protocol will specify other column type if required)

- High purity hydrogen, nitrogen and air
- CGA 350, 580 and 590 gas cylinder regulators with 1/8-inch tubing connectors
- 1,000 cc gas syringe
- Printer (optional as all chromatography files are saved)

SAMPLING PROCEDURES

- Assemble the sampling system and conduct a leak check.
- For critical orifice flow controllers, calibrate the sampling rate with a gas flow calibrator.
- Set sampling rate to fill a Tedlar bag approximately 80% full over the test period. A typical sampling rate is 0.16 liters per minute to collect a 9.6 liter sample in a 12 liter bag over a 1-hour period.
- Position the probe at the first sampling point and purge the system for at least two times the response time.
- Record sampling data on a prepared form. Sampling data may include dry gas meter volume, flow meter ball level, temperature, vacuum and pressure.

ANALYTICAL PROCEDURES

- Set up SRI Model 8610C chromatograph in accordance with manufacturer specifications.
- Confirm that all calibration gas certifications are complete and not expired.
- Conduct a 3-level calibration on the gas chromatograph for each target compound using commercially available gas standards. Each gas standard must be analyzed three times and the responses must be within 5% of the mean for each target compound.
- Analyze samples after completing the initial calibration. Samples are also analyzed in triplicate and responses must be within 5% of the mean.
- Periodically analyze zero grade nitrogen or air to demonstrate system is contamination free.
- Prepare a bag recovery spike using one of the sample bags. The recovery spike is prepared using a gas syringe (see attached photograph) and one of the calibration standards. Inject a volume of standard gas into the sample bag to increase the target compound concentration by 40-60%. Analyze the spiked sample in triplicate and calculate recovery using the Method 18 controlled spreadsheet. Sample values are corrected using a spike recovery factor.
- After completing sample analyses, re-analyze the mid-level calibration gas in triplicate. If the average value of each target compound is within 5% of the initial value, the initial calibration can be used to quantify the samples. If the post-test calibration varies by more than 5% of the initial calibration, then the 3-point calibration must be repeated and both pre and post-test calibrations must be used for sample quantification.

QUALITY ASSURANCE

Sampling System:

- Sample flow rate should be ±2%.
- Leak rate should be 0.00 liters per minute at 5 inches Hg vacuum

Chromatography Analysis:

- Standards, samples and spikes must be analyzed in triplicate and responses must be within 5% of the mean.
- Spike recovery must be within 70 – 130%.

Calibration Gas:

- Calibration uncertainty of ≤ 2% certified value
- Gas used only prior to expiration date

CALCULATIONS

Triplicate Injection:

$$\text{Dev} = \frac{(\text{RPavg - RP})}{RPavg}\ x\ 100$$

RP Chromatograph response in area units
RP_{avg} Average response of three injections
Dev Deviation from the mean value

Drift Assessment:

$$D = |SB_{final} - SB_i|$$

D Drift assessment, percent of calibration span
SB_{final} Post-run system response for the mid-level gas
SB_i Pre-run system response for the mid-level gas

Spike Recovery Correction:

$$C_{Gas} = C_{Avg}\ x\ R$$

C_{Gas} Average effluent gas concentration adjusted for spike recovery, ppmv
C_{Avg} Average unadjusted gas concentration for the test run, ppmv
R Recovery Factor

Recovery Study:

EPA Method 18 Section 8.4.2 Recovery Study for Bag Sampling Example Calculation

	Sample ID	Post Analysis Sample Volume (l)	Un-Spiked Sample Response (u) (ppm)	Compound Volume in Sample (ul)	Standard Volume Added to Sample (L)	Standard Conc (ppm)	Compound Volume from Standard (ul)	Spiked Bag Total Conc (ppm)	Theoretical Spike Conc (s) (ppm)	Spiked Sample Response (t) (ppm)	(t-u)/s Recovery (%)
Compound 1	Run 1	6.977	0.0	0.0	0.400	9.4	3.752	0.51	0.51	0.50	98.3%

Spiked Sample Analysis

	Concentration (ppm)						
Injection No.	1	2	3	average (t)	Deviation		
Compound 1	0.50	0.50	0.50	0.50	0.0%	0.0%	0.0%

Recovery = (t-u)/s x 100
= (0.50-0.00)/0.51 x 100 = 98.3%

Bag Sample Volume meter Y= 0.9828

Temp (^oF)	Meter Volume (liters)	Pbar	Standard Volume (liters)
60.0	7.055	30.08	7.127

Sample Volume Used for Initial Analyses

# of injections	rate (cc/min)	time (min)	Volume (liters)
3	50	1	0.15

Detection Limit

Detection limit is determined by analyzing the low standard seven times and applying a standard statistical analysis. An example of the detection limit determination is shown below.

Standard Conc (ppm)	Response (ppm) [1]							Average	Standard Deviation	MDL (ppm) [2]
	1	2	3	4	5	6	7			
1.00	1.181	1.129	1.166	1.171	1.183	1.185	1.182	1.1710	0.020	0.062

1. The low standard is analyzed 7 consecutive times.
2. MDL (ppm) = STDEV x 3.143
   STDEV = standard deviation of the response for 7 injections of the low standard
   3.143 = Student T-value for n-1 degrees of freedom at a 99% confidence

Mass Emission Rate

Polllutant mass emission rate in pounds per hour (lb/hour) is calculated from the measured concentration and exhaust gas flow rate as follows:

$$ER = \text{ppmw x molecular weight x scfm x } 15.58 \times 10^{-8}$$

ER = emission rate (lb/hour)

ppmw = parts per million by volume – wet basis

scfm = standard cubic feet per minute (wet)

Mass Basis Destruction Efficiency

Mass basis destruction efficiency is calculated with measured pollutant flow rates at the control device inlet and outlet using the following calculation:

$$\text{Destruction Efficiency (\%)} = (ER_{in} - ER_{out})/ER_{in} \times 100$$

ER_{in} = control device inlet pollutant flow rate (lb/hour)

ER_{out} = control device outlet pollutant flow rate (lb/hour)

Component Images

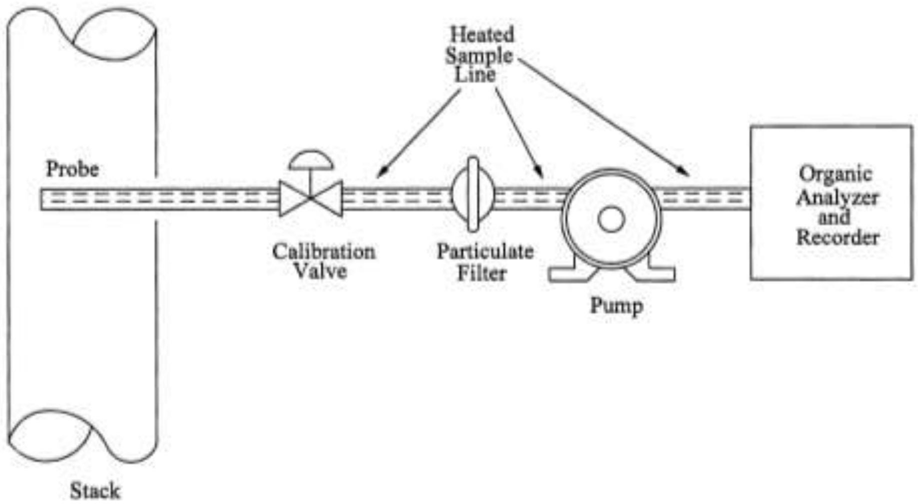
SRI, Inc. Model 8610C Gas Chromatograph:

EPA Method 18 Bag Sampling Device and Gas Syringe for Recovery Study:

SUMMARY

A gas sample is extracted from the source through a heated sample line and glass fiber filter to a flame ionization analyzer.

SAMPLING TRAIN



<u>Components</u>:

- Stainless steel probe heated to ≥ 220 °F.
- A glass fiber in-stack filter or a glass fiber out-of-stack filter heated to ≥ 220 °F. The filter is not required where no significant particulate matter is present.
- Teflon or stainless steel sample line heated to ≥ 220 °F.
- Leak-free pump constructed of non-reactive material to pull sample through the system at a sufficient rate to minimize the response time.
- Manifold constructed of non-reactive material to allow the introduction of calibration gases into the measurement system at the probe.
- Flame ionization analyzer capable of meeting all performance requirements.
- Computer based data acquisition system for recording measurements.

SAMPLING PROCEDURES

- Assemble the sampling system and conduct a leak check.
- Confirm that all calibration gas certifications are complete and not expired.
- Conduct an analyzer calibration error test sending gas through the entire measurement system.
- Conduct a response time test.
- Position the probe so that sample is collected from the centrally located 10% area of the stack.
- Begin sampling after ≥ 2 times the sampling response time has passed.
- Conduct a post-run drift assessment check.

QUALITY ASSURANCE

Measurement System:

- Calibration error is verified to be within ±5% of the calibration gas value
- Drift is verified to be within ±3% of the span value

NO_X Analyzer:

- Analyzer used for testing has undergone manufacturer interference checks
- Analyzer resolution is < 2.0% full-scale range

Calibration and Support Gas:

- Calibration uncertainty of ≤ 2% certified value
- High purity air zero gas < 0.1 ppmv organic material
- Low-level calibration gas 25-35% of the applicable span value
- Mid-level gas 45-55% of the applicable span value
- High-level gas 80-90% of the applicable span value
- Fuel consisting of 100% H_2

Data:

- Data collection and calculations are conducted on a reviewed computer based system
- Data resolution ≤ 0.5% full-scale range
- Data recording frequency of ≤ 1-minute average
- Minute averages ≤ calibration span
- Run average ≤ calibration span

CALCULATIONS

Analyzer Calibration Error:

$$\text{ACE} = \frac{C_S\text{-}C_V}{C_\mathrm{V}}\ x\ 100$$

ACE Analyzer calibration error, percent of calibration gas value
C_S Measured concentration of a calibration gas through the sampling system, ppmv
C_v Manufacturer certified concentration of a calibration gas (low, mid, high), ppmv

Drift Assessment:

$$\text{D} = \frac{C_S\text{-}C_i}{CS}\ x\ 100$$

D Drift assessment, percent of span
C_S Measured concentration of a calibration gas through the sampling system, ppmv
C_i Initial analyzer response, ppmv
CS Calibration span, ppmv